# Groundwater Sustainability Plan

## Monterey Subbasin

Marina Coast Water District Groundwater Sustainability Agency

Salinas Valley Basin Groundwater Sustainability Agency

## DRAFT Chapter 5

## Current and Historical Groundwater Conditions

September 2021

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# 5 CURRENT AND HISTORICAL GROUNDWATER CONDITIONS

This section presents information on historical and current groundwater conditions within the Subbasin based on available data. The GSAs gathered information from multiple monitoring agencies within the subbasin to establish the best comprehensive understanding of the Subbasin's groundwater conditions. Source of data used to inform this assessment include data from Marina Coast Water District (MCWD), Monterey County Water Resources Agency (MCWRA), Fort Ord, Monterey Peninsula Water Management District (MPWMD), California Department of Water Resources (DWR), United States Geological Survey (USGS), Monterey Peninsula Landfill, and Seaside Groundwater Basin Watermaster records, various state and federal databases, and other reports.

For the purpose of this Chapter:

(a) "Current Conditions" or "Current Period" refers to third quarter 2017 and second quarter 2018.

(b) "Historical Conditions" or "Historical Period" refers to Water Years (WY) 2004 through 2018 (i.e. October 2003 through September 2018).

The 15-year Historical Conditions period is used to develop the historical water budget as well as assess groundwater elevation and water quality trends. As discussed further below, this period is climatically close to normal/average rainfall conditions measured in the vicinity of the Subbasin since 1895. It includes a significant drought period between 2012 and 2015, as well as other drier and wetter than normal years. In some cases, other periods of record are also discussed in this section when either (a) the discussion is constrained by the time periods of available datasets (e.g., for land subsidence), or (b) characterization of groundwater conditions is improved by incorporation of data from other time periods.

This chapter summarizes information related to the six sustainability indicators defined under the Sustainable Groundwater Management Act (SGMA), including:

1. Chronic lowering of groundwater levels;
2. Changes in groundwater storage;
3. Seawater intrusion
4. Groundwater quality;
5. Subsidence; and
6. Depletion of interconnected surface waters.

In addition, the chapter discusses groundwater dependent ecosystems (GDEs). GDEs are not a SGMA-defined sustainability indicator but are an important part of GSPs.

As discussed in the Hydrogeological Conceptual Model (HCM), the principal aquifers of the Marina-Ord area being mostly the same as the layered principal aquifers in the 180/400-Foot Aquifer Subbasin, and the principal aquifer in the Corral de Tierra area being the El Toro Primary Aquifer System, which combines the water-bearing geologic units into one functional aquifer. The Dune Sand and 180-Foot aquifers, and their unique geology are not present in the Corral de Tierra Area. However, the Aromas Sands, Paso Robles

Formation, and the Santa Margarita Sandstone are present across the subbasin and are the foundation for the aquifers defined in Chapter 4. The hydrologic connection between these two areas is undefined with the best available data and information, but the presence of the same geologic units indicates some connection. The groundwater conditions outlined below are the best attempt to describe both the unique areas as well as the connection despite the uncertainty, and with the understanding that implementation actions will begin to address these data gaps.

## 5.1 Groundwater Elevations and Flow Direction

Subbasin groundwater elevations are presented using the following methodologies:

- Maps of groundwater elevation contours that show the geographic distribution of groundwater elevations at a specific time. The contours represent lines of equal groundwater elevation in feet above the NAVD88 vertical datum.
- Hydrographs of individual wells that show the variations in groundwater elevation at individual wells over an extended period.
- Vertical hydraulic gradients in a single location that assess the potential for vertical groundwater flow direction.

### 5.1.1 Data Sources

Groundwater elevations have been assessed based on data collected and compiled from various agencies including MCWD, MCWRA, Fort Ord, MPWMD, DWR's California Statewide Groundwater Elevation Monitoring (CASGEM) database, USGS, Monterey Peninsula Landfill, and Seaside Groundwater Basin Watermaster. Multiple datasets were reconciled and processed for quality assurance/quality control prior to analysis of groundwater conditions. These "data cleaning" efforts included identification and removal of potentially erroneous data points through examination of hydrographs and information recorded based on the quality of the measurement. For the purposes of this analysis, the periods of Fall 2017 and Spring 2018 and are used to represent seasonal low and high conditions during the Current Period. They are also considered representative of current land and water use conditions.

### 5.1.2 Groundwater Elevation Contours and Horizontal Groundwater Gradients

Groundwater elevation contours for each principal aquifer during Fall 2017 and Spring 2018[1] are presented on Figure 5-1 to Figure 5-10. Groundwater flow directions and groundwater levels observed during these periods in the Marina-Ord Area and Corral de Tierra Area are summarized below.

[1] Data between 15 August and 15 December 2017 are used to develop groundwater contours for the Fall 2017 season. For wells that have multiple measurements during this period, priority was given to measurements taken closer to 27 August 2017. Data between 15 January and 15 April 2018 are used to develop groundwater contours for the Spring 2018 season, with priority given to measurements taken closer to 5 March 2018.

#### *5.1.2.1 Marina-Ord Area*

The Principal Aquifers in the Marina Ord Area include: the Dune Sand Aquifer, 180-Foot Aquifer, 400-Foot Aquifer, and Deep Aquifers. In the Marina-Ord Area, the 180-Foot Aquifer contains two distinct layers, known as the upper- and lower- 180-Foot Aquifer. Conditions in both layers of the 180-Foot Aquifer are described herein. Both layers are hydraulically connected to the Principal Aquifer known also known as the 180-Foot Aquifer in the adjacent 180/400-Foot Aquifer Subbasin.

**Dune Sand Aquifer**

As discussed in Chapter 4 and shown in Figure 5-1 and Figure 5-5, the Dune Sand Aquifer only exists in the Marina-Ord Area within the dune sand deposits located in the western portion of the subbasin.

- Groundwater elevations in the Dune Sand Aquifer range from 90 ft NAVD88 in the central portion of the Marina-Ord Area to approximately 5 ft NAVD88 near the coast where the Dune Sand Aquifer merges with the upper 180-Foot Aquifer, west of the SVA. Groundwater level data for the Dune Sand Aquifer are limited in the southern portion of the Marina-Ord Area near the Monterey-Seaside Subbasin boundary and at the eastern extent of the dune sands.
- A groundwater divide exists in the Dune Sand Aquifer within the Marina-Ord Area. West of the groundwater divide, groundwater in the Dune Sand Aquifer flows westward towards the Pacific Ocean and recharges the 180-Foot Aquifer where the SVA pinches out. Upon entering the 180-Foot Aquifer, groundwater abruptly reverses direction and flows eastward (i.e., inland). East of the groundwater divide, groundwater in the Dune Sand Aquifer flows to the northeast toward the 180/400-Foot Aquifer Subbasin and the Salinas River.
- During the Current Period, the average magnitude of the horizontal gradient in the Dune Sand Aquifer was approximately 0.011 ft/ft west of the groundwater divide and 0.007 ft/ft east of the groundwater divide.

**180-Foot Aquifer**

The 180-Foot Aquifer is subdivided into the upper 180-Foot Aquifer and the lower 180-Foot Aquifer in the Marina-Ord Area, based on the stratigraphy described in multiple studies focused on this area (Ahtna Engineering, 2013; Harding ESE, 2001; detailed in Chapter 4). Groundwater elevations and gradients observed in these two zones of the 180-Foot Aquifer are described below.

*Upper 180-Foot Aquifer*

- Groundwater elevations in the upper 180-Foot Aquifer are highest at the coastline and generally decrease inland to the east/northeast. Flow directions are generally to the northeast toward the 180/400 Foot Aquifer Subbasin.
- In Fall 2017 (Figure 5-2), groundwater elevations range from 5 ft NAVD88 along the coast to -20 ft NAVD88 at the Monterey-180/400 Foot Aquifer Subbasin boundary. Groundwater elevations are generally higher in Spring 2018. This increase is likely the result of increase recharge and reductions in pumping in the Salinas Valley Basin.

- Groundwater elevations are near sea level at the coastline and are below sea level further inland. This inland gradient allows high salinity water to flow into the Subbasin (see Section 5.3 Seawater Intrusion). However, inflow from the Dune Sand Aquifer protects the upper 180-Foot Aquifer from seawater intrusion. The Dune Sand Aquifer merges with the upper 180-Foot Aquifer near the coast, resulting a gradient toward the Pacific Ocean.

- During the current period, the average horizontal gradient in the 180-Foot Aquifer was 0.0012 ft/ft in Fall 2017 and 0.0008 ft/ft in Spring 2018 (Figure 5-6).

*Lower 180-Foot Aquifer*

As discussed in Chapter 4, the lower 180-Foot Aquifer is hydraulically connected to the 400-Foot Aquifer in the in the Marina-Ord Area due to the discontinuous nature of the 180/400-Foot Aquitard within this region. As such, groundwater elevations and gradients in the lower 180-Foot Aquifer are similar to those in the 400-Foot Aquifer in the Marina Ord Area of the Subbasin, which are further described below.

**400-Foot Aquifer**

Figure 5-3 and Figure 5-7 show groundwater elevation contours within the 400-Foot Aquifer in the Marina-Ord Area. These groundwater elevations and gradients are consistent with those observed in the lower-180 Foot Aquifer. Groundwater elevations in the 400-Foot Aquifer have been plotted in combination with groundwater elevations within the Paso Robles Aquifer identified in the adjacent Seaside Subbasin. Available data indicates that these aquifers are potentially hydraulically connected. However, there is also a possible connection between the Seaside Subbasin Paso Robles Aquifer with the upper portion of the Deep Aquifers in the Monterey Subbasin.

- Groundwater elevations in the 400-Foot Aquifer are highest in the southern portion of the Monterey Subbasin and generally decrease to the north and east. Flow directions are generally toward the northeast and the 180/400 Foot Aquifer Subbasin. A flow divide occurs along the Monterey-Seaside Subbasin boundary.

- A local groundwater depression exists just north of the Monterey-Seaside Subbasin boundary where a potential connection between the 400-Foot Aquifer and the Deep Aquifers may be located (see Section 5.1.3).

- In Fall 2017, groundwater elevations in the Marina-Ord Area ranged from 0 ft NAVD88 at the coast to -40 ft NAVD88 at the Monterey-180/400 Foot Aquifer Subbasin boundary. Groundwater elevations are generally higher in Spring 2018. This increase is likely the result of increased recharge and reductions in pumping in the Salinas Valley Basin.

- Groundwater elevations are near sea level at the coastline and below sea level further inland. Based on available cross-sections (e.g. Harding ESE, 2001; see Chapter 4), the formations that make up this aquifer extend offshore, and likely outcrop beneath a veneer of Pleistocene or Holocene marina sediments that is thin (i.e. less than 5 meters) across much of the offshore shelf but thicker (i.e. up to 32 meters) near the Salinas River Delta (Johnson et al., 2016). These conditions allow high salinity water to flow into this aquifer in the northern portion of the Subbasin.

- During the Current Period, the average magnitude of the horizontal gradient in the 400-Foot Aquifer was 0.0011 ft/ft in Fall 2017 and 0.0006 ft/ft in Spring 2018.

**Deep Aquifers**

As discussed in Chapter 4, the Deep Aquifers consist of multiple aquifers and aquitards that appear to be somewhat hydraulically connected. Given the absence of data for the multiple layers that make up this aquifer, this assessment generally describes conditions in the Deep Aquifers as a whole.

Figure 5-4 and Figure 5-8 show groundwater elevation contours within the Deep Aquifers in combination with groundwater elevation contours within the Santa Margarita Aquifer in the Seaside basin. Available data indicate that these aquifers are potentially hydraulically connected.

- Groundwater elevations in the Deep Aquifers are highest in the southeastern portion of the Marina-Ord Area and generally decrease toward the northwest. Flow directions are generally toward the north, suggesting some recharge from mountain ranges south of the Subbasin and flow into a pumping trough just north of the Monterey-180/400-Foot Aquifer Subbasin boundary near West Blanco Rd and Nashua Rd. A local groundwater high exists just north of the Monterey-Seaside Subbasin boundary between the Seaside Subbasin and Monterey-180/400-Foot Aquifer Subbasin pumping centers.
- In Fall 2017, groundwater elevations range from 160 ft NAVD88 near the southeastern Subbasin boundary to -60 ft NAVD88 in the north near the Monterey180/400-Foot Aquifer Subbasin boundary. Groundwater elevations are generally higher in Spring 2018.
- During the Current Period, the average magnitude of horizontal gradient in the Deep Aquifers, identified on the basis of contours shown on Figures 5-1 and 5-2, ranged between 0.0006 ft/ft in Fall 2017 to 0.0004 ft/ft in Spring 2018 in the Marina Ord Area. However, since groundwater elevations shown on these figures may represent multiple aquifers within the Deep Aquifers due to varying screen lengths and depths, the direction and magnitude of these gradients may not accurately represent conditions throughout the Deep Aquifers.
- Groundwater elevations in the Deep Aquifers are significantly lower than those in the 400-Foot Aquifer and have been consistently below sea level since the late 1980s. These data suggest that the Deep Aquifers is at risk of seawater intrusion from locations where these formations outcrop on the ocean floor near the rim of the Monterey Canyon (Hartwell et al., 2015; Johnson et al., 2016) and from leakage from the overlying seawater intruded aquifers.

#### *5.1.2.2 Corral de Tierra Area*

Figure 5-9 through Figure 5-10 show groundwater elevation contours within the El Toro Primary Aquifer System in the Corral de Tierra Area. Groundwater in the El Toro Primary Aquifer System generally flows from the south toward the north, northwest, and northeast with a potential groundwater flow divide occurring near the Monterey-Seaside Subbasin boundary in the Laguna Seca area. There are a few localized depressions around pumping centers, as shown in the groundwater elevation contours in the following figures. Additionally, the Monterey Formation, which is the bottom of the basin, is uplifted in this locale due to structural deformation and may impact some flow direction. In Fall 2017, the groundwater elevations in the El Toro Primary Aquifer System ranged from approximately **800 ft to -40 ft** NAVD88 from south to north.

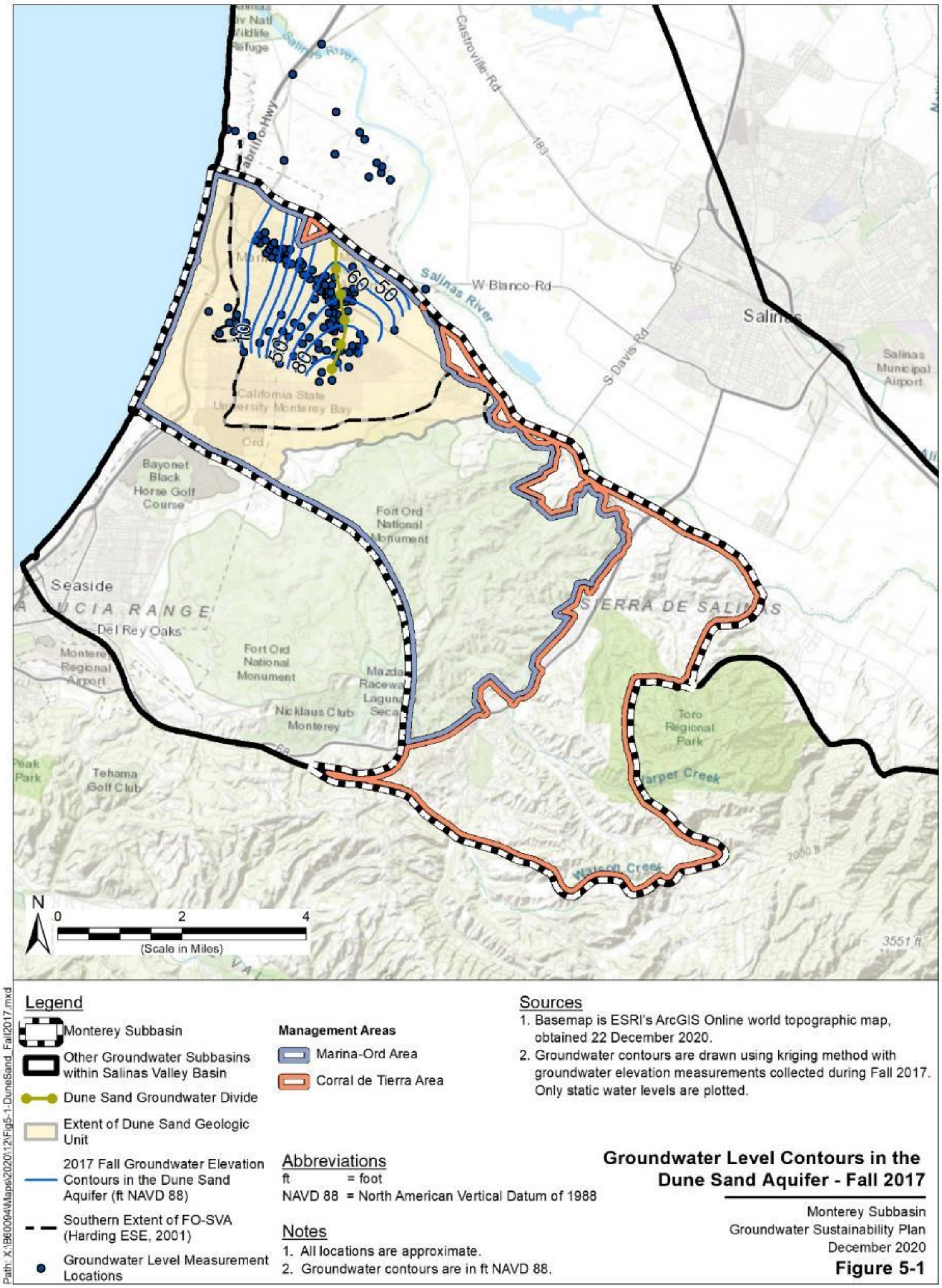



**Figure 5-1. Groundwater Elevation Contours in the Dune Sand Aquifer - Fall 2017**

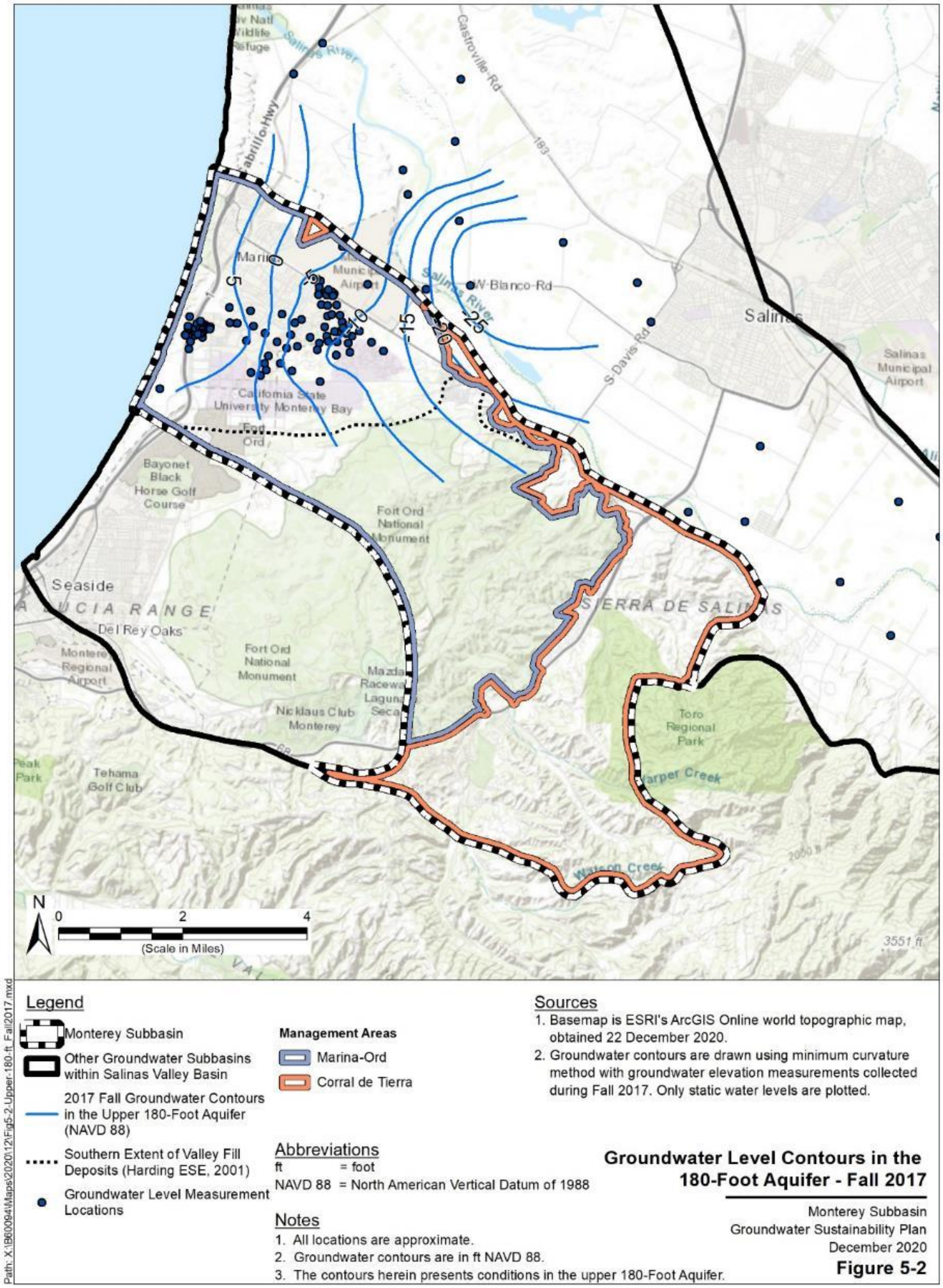



**Figure 5-2. Groundwater Elevation Contours in the 180-Foot Aquifer - Fall 2017**

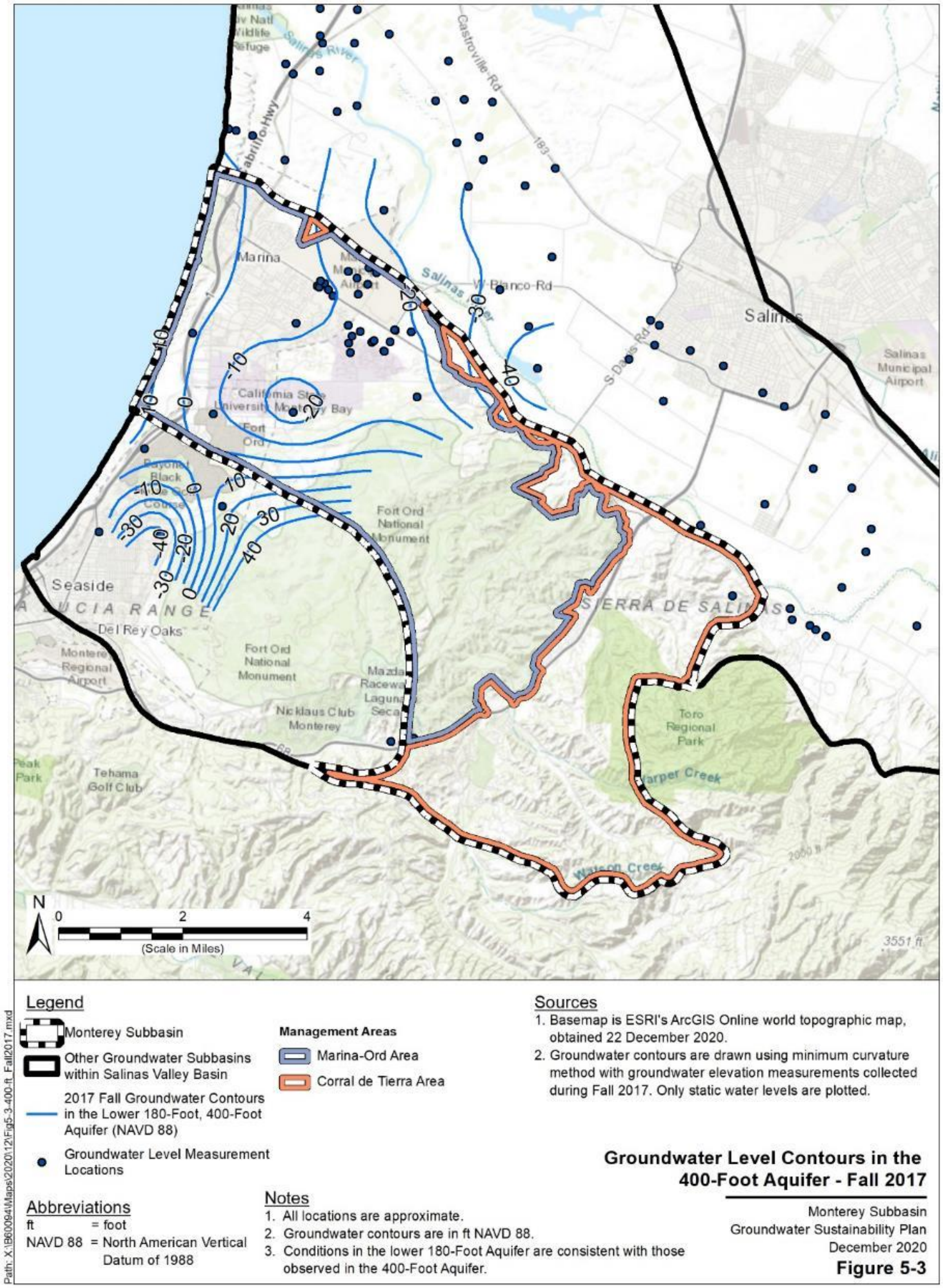



**Figure 5-3. Groundwater Elevation Contours in the 400-Foot Aquifer - Fall 2017**

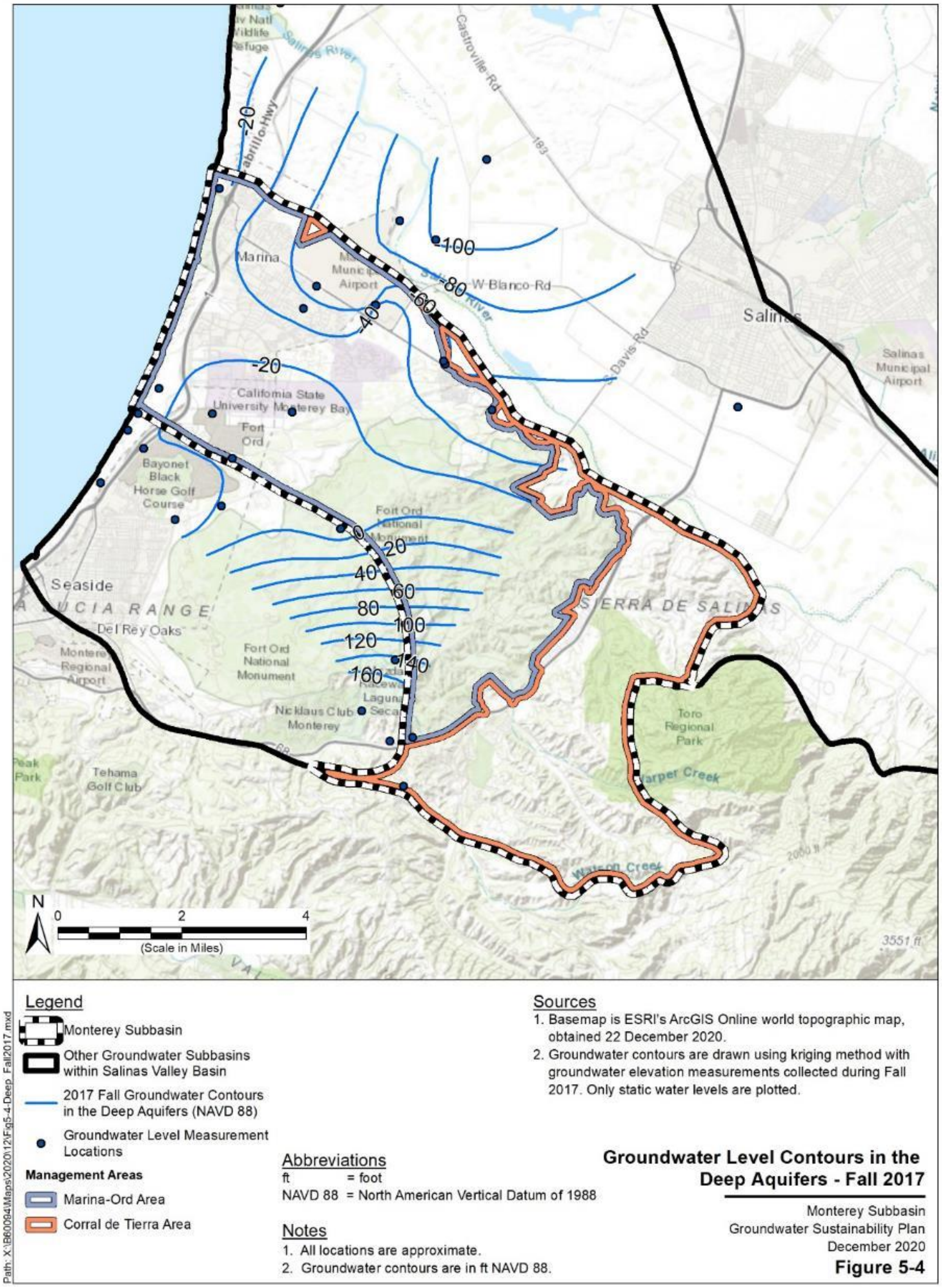



**Figure 5-4. Groundwater Elevation Contours in the Deep Aquifers - Fall 2017**

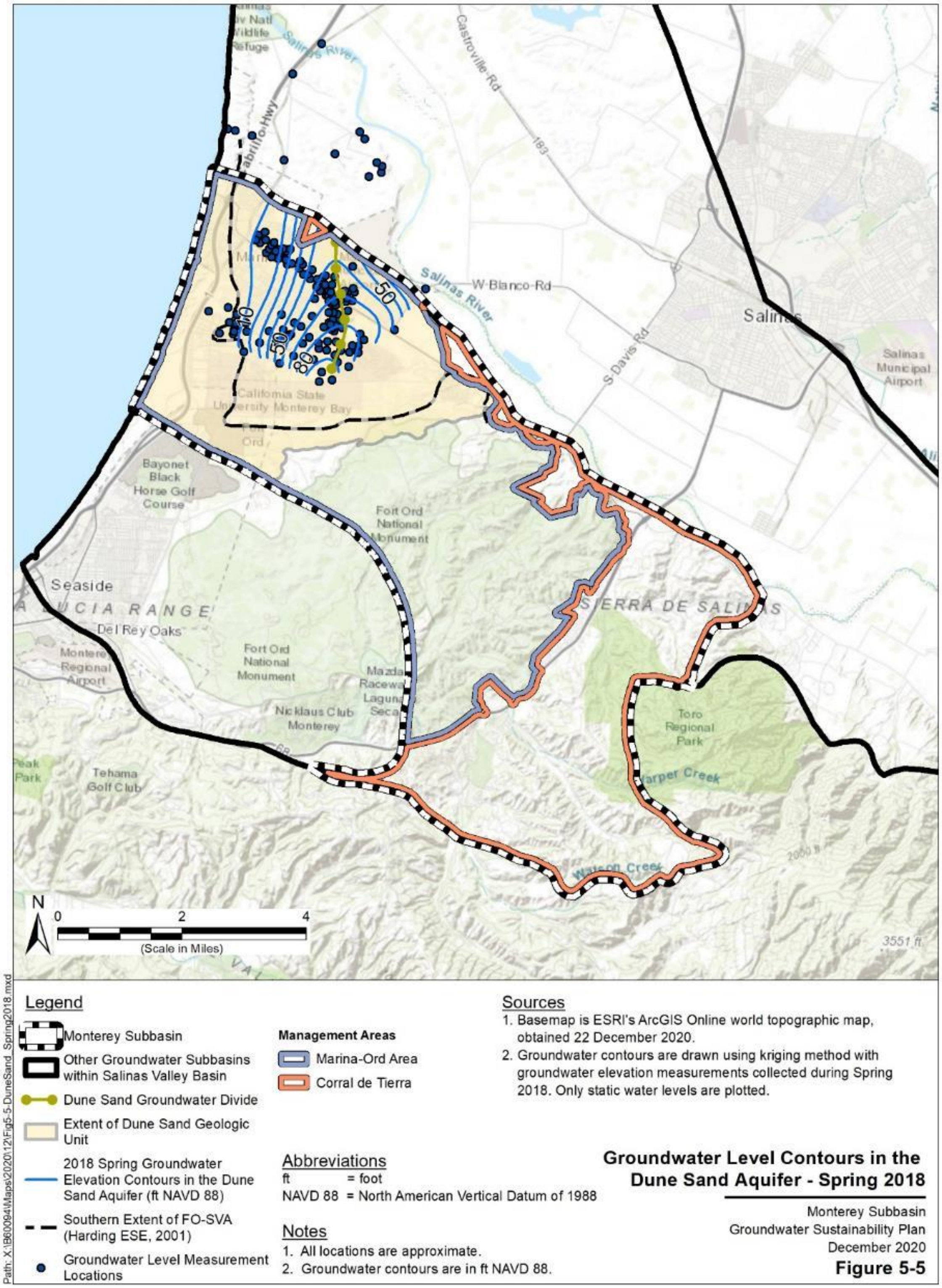



**Figure 5-5. Groundwater Elevation Contours in the Dune Sand Aquifer – Spring 2018**

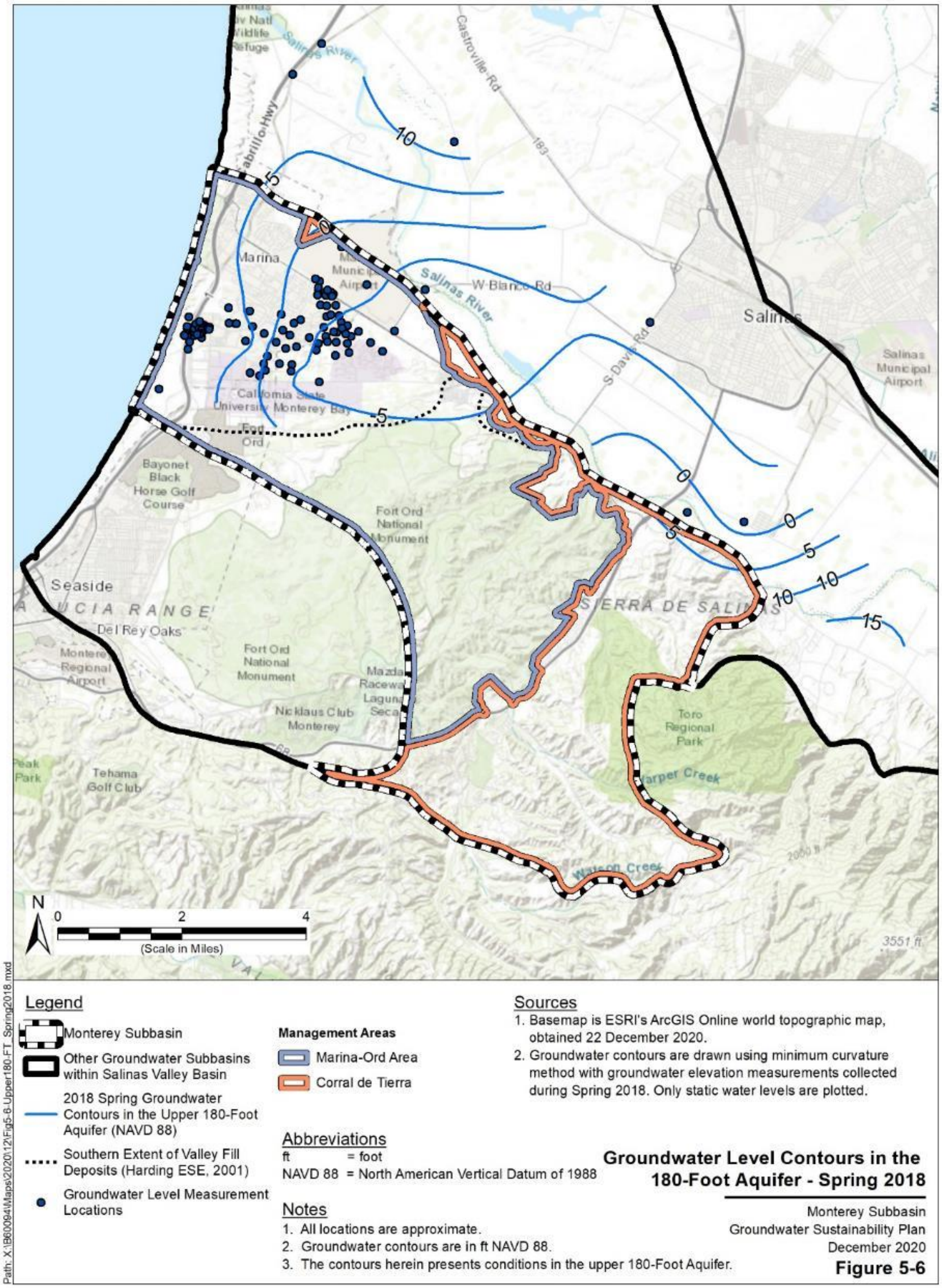



**Figure 5-6. Groundwater Elevation Contours in the 180-Foot Aquifer – Spring 2018**

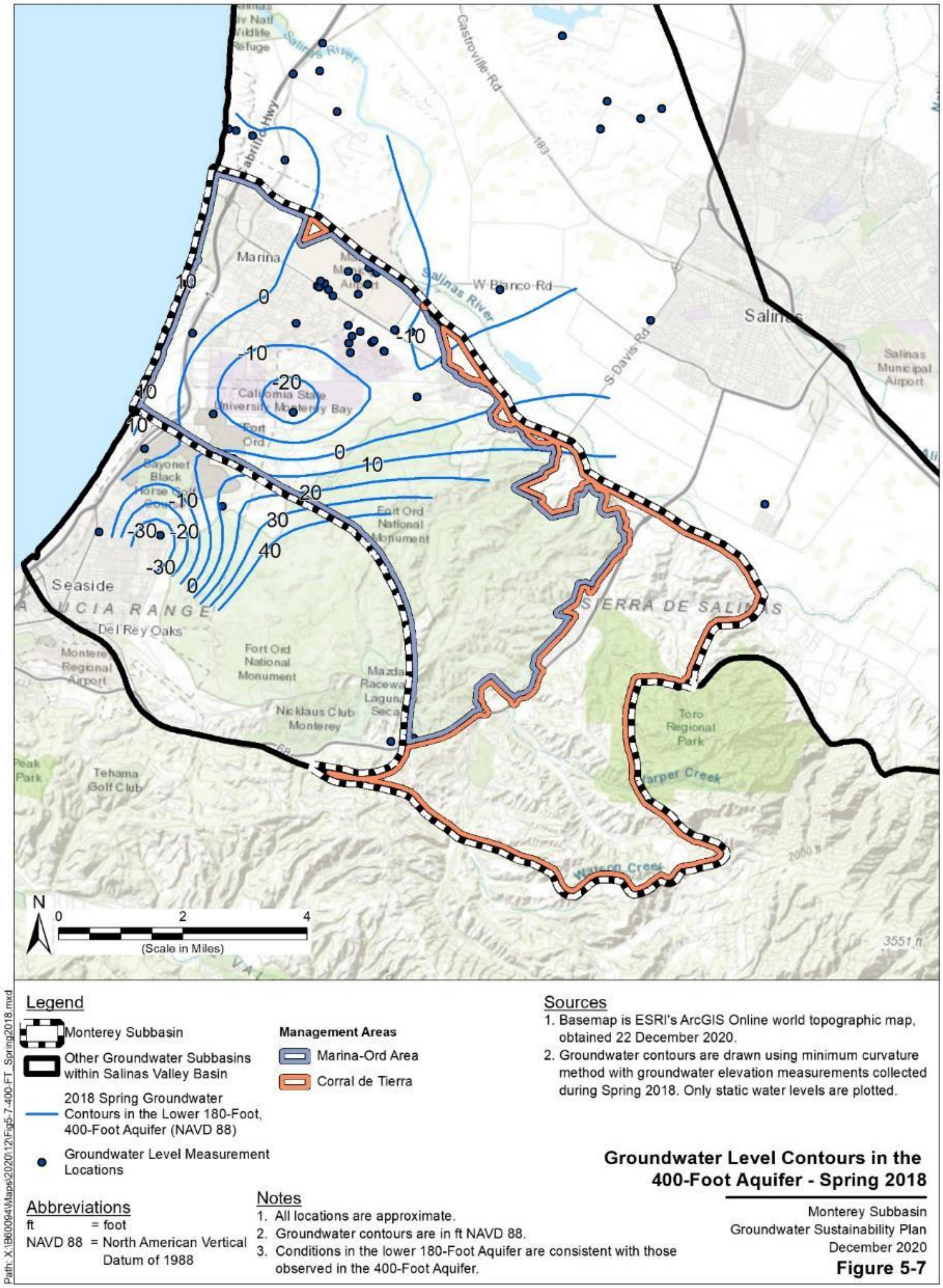



**Figure 5-7. Groundwater Elevation Contours in the 400-Foot Aquifer – Spring 2018**

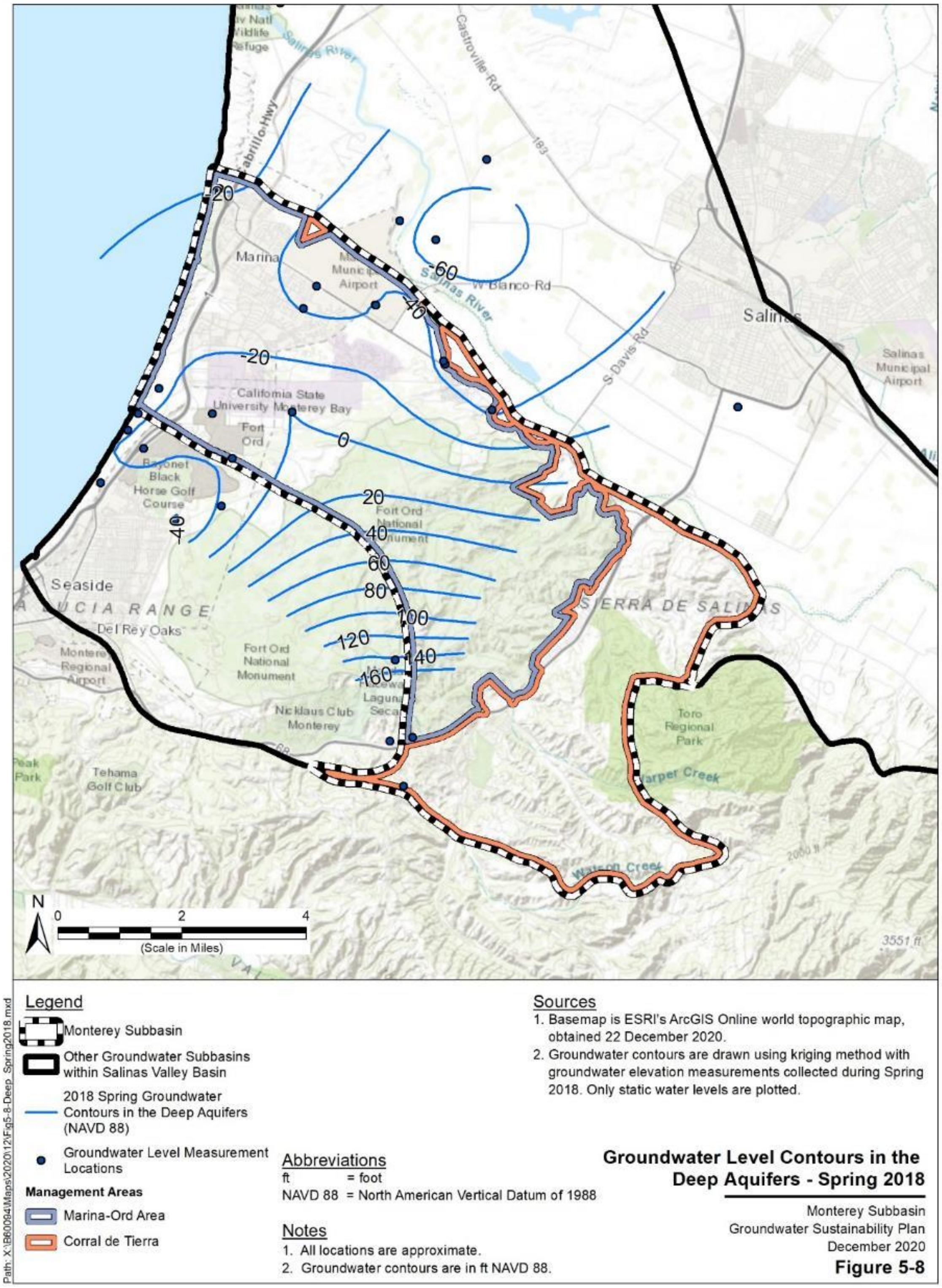



**Figure 5-8. Groundwater Elevation Contours in the Deep Aquifers – Spring 2018**

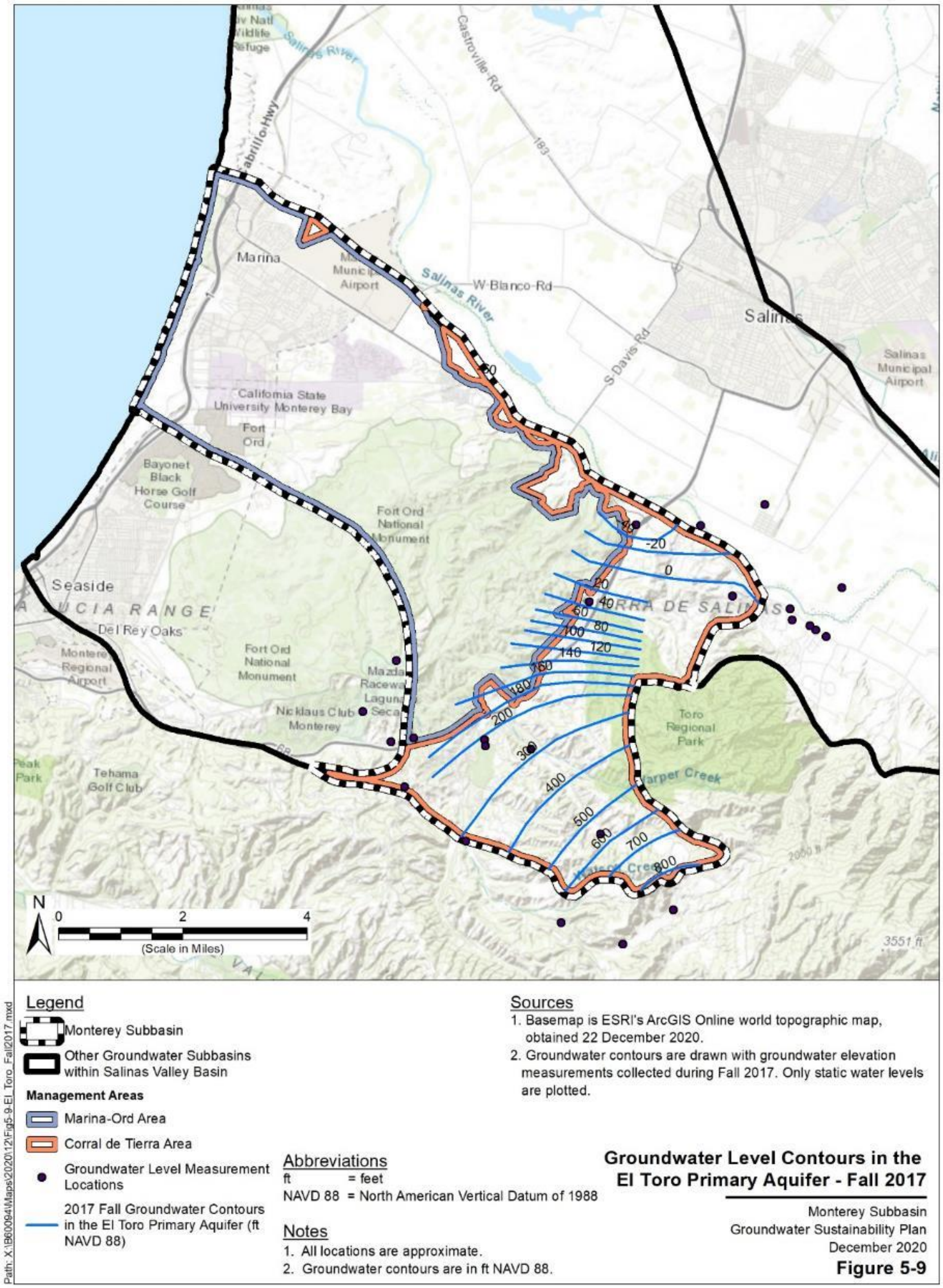



**Figure 5-9. Groundwater Level Contours in the El Toro Primary Aquifer - 2017 Fall**

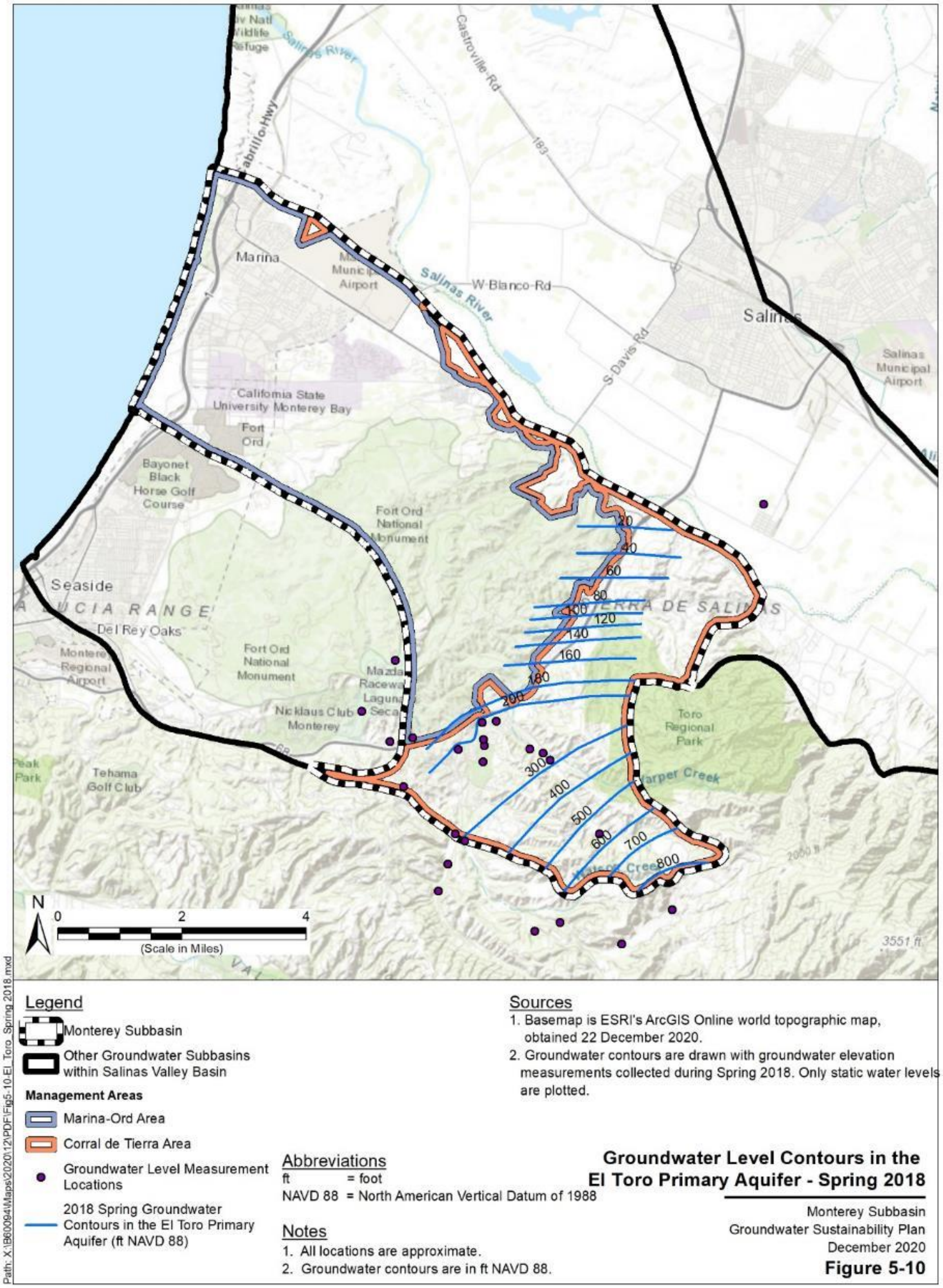



**Figure 5-10. Groundwater Level Contours in the El Toro Primary Aquifer - 2018 Spring**

### 5.1.3 Long-Term Groundwater Elevation Trends

Representative temporal trends in groundwater elevations can be assessed with hydrographs that plot changes in groundwater elevations over time. Wells were selected for hydrograph analysis based on their length of record and location. Wells believed to be representative of conditions across various areas of the Subbasin were selected. Additionally, a linear regression of the water level data over a 15-year period (i.e. 2004 through 2018) was used to evaluate long-term groundwater elevation trends for selected wells.

Figure 5-11 through Figure 5-15, and Figure 5-17 depict the locations and hydrographs of representative wells within each principal aquifer and their hydrographs. The large versions of the hydrographs for these wells, as well as other representative monitoring wells, are included in Appendix 8-A. The following sections summarize trends in groundwater elevations within each principal aquifer within the Marina-Ord Area and the Corral de Tierra Area.

#### *5.1.3.1 Marina-Ord Area*

**Dune Sand Aquifer**

- Groundwater elevations in the Dune Sand Aquifer have been generally stable for over three decades and do not show large seasonal variations, unlike the groundwater elevations in the deeper aquifers which show large seasonal variations due to agricultural pumping in the neighboring Salinas Valley groundwater subbasins. Consistent with most shallow unconfined aquifers that receive direct recharge from rainfall, water levels in the Dune Sand Aquifer increase and decrease during extended wet and dry periods. Most wells in this aquifer show slightly decreasing trends during the past 15 years following a prior period of increasing water levels. Linear trendline slopes over this period ranged from -0.761 feet per year (ft/yr) to 0.0222 ft/yr (Figure 5-11).

**180-Foot Aquifer**

*Upper 180-Foot Aquifer*

- Groundwater elevations have been stable in the past thirty years. During the past 15 years, wells in this aquifer have shown no significant trend. Linear trendline slopes over this period ranged from -0.0363 ft/yr to 0.0161 ft/yr (Figure 5-12). Seasonal fluctuations in this aquifer have been as large as 10 ft.

*Lower 180-Foot Aquifer*

- Groundwater elevations in the Lower 180-Foot Aquifer are generally equivalent to those observed in the 400-Foot Aquifer, which are described below.

**400-Foot Aquifer**

- Groundwater elevations have been stable over the past thirty years in wells in this aquifer in the northern Marina-Ord Area. During the past 15 years, groundwater elevation trends in wells screened in the 400-Foot aquifer in this area have been generally flat. Linear trendline slopes over the last 15-year period ranged from -2.05 ft/yr to 0.108 ft/yr (Figure 5-13). Seasonal fluctuations in this aquifer have been as large as 30 ft.

Two CASGEM wells in the southwestern portion of the Marina-Ord Area, MPWMD#FO-10 and MPWMD#FO-11, show consistent decreasing trends over the past 15-years. Additionally, groundwater elevations in these wells are significantly lower than those to the north near the City of Marina and to the south in the Seaside Subbasin. When water levels in these wells are plotted in conjunction with other 400-Foot Aquifer wells in the Marina Ord Area, they indicate the presence of in a localized depression in the groundwater potentiometric surface of the 400-Foot Aquifer. However, there is no known extraction in the Monterey Subbasin in the vicinity of these wells and groundwater elevations observed in these wells are similar to those measured in the Deep Aquifers. These data suggest that (1) these wells are screened within sediments that connect directly to the Deep Aquifers; or (2) leakage is occurring from the 400-Foot Aquifer into the Deep Aquifers in the vicinity of these wells.

- Groundwater production from the Deep Aquifers in the 180/400-Foot Aquifer Subbasin began in the mid-1970s. Within the Monterey Subbasin, MCWD's production in the Deep Aquifers began in 1985. At this time, groundwater elevations were close to sea level in the Deep Aquifers within the Marina-Ord Area of the Monterey Subbasin (Feeney and Rosenberg, 2003).
- Groundwater elevations in the Deep Aquifers within the Marina-Ord Area declined rapidly in the first few years of MCWD's extraction from the Deep Aquifer, but stabilized beginning in the early 1990s, and stayed stable through the mid-2000s. During this time period, rates of groundwater extraction from the Deep Aquifers ranged from 2,000 AFY to 2,300 AFY from MCWD wells. Rates of groundwater extraction from 180/400-Foot Aquifer Subbasin agricultural production wells were approximate 2,000 AFY during this period, resulting in a combined production rate of approximately 4,000 AFY from the Deep Aquifers (Figure 5-16)[2].
- Groundwater elevations in the Deep Aquifers have shown a consistent decline since the mid-2000s. Linear trendline slopes in representative wells within the Marina-Ord area over the past 15 years have ranged from -2.79 ft/yr to -0.747 ft/yr (Figure 5-14 and Figure 5-15).
- The USGS multi-completion well (014S001E24L) near the Monterey Coast shows varying potentiometric heads between screen intervals with similar long-term trends. These data indicate that the Deep Aquifers are comprised of series of aquifer zones and aquitards that are influenced by groundwater production within these zones. As evidenced by groundwater elevations measured in 014S001E24L and 14S02E33E, groundwater elevations in the upper portion of the Deep Aquifers (approximately 900 ft bgs) are lower than those in the lower portion of the Deep Aquifers (approximately 1,500 ft bgs). Groundwater elevation trends in the upper portion of the

[2] During this period, MCWD and MCWRA entered into the 1996 Annexation Agreement (see Section 3.2.2.2) where the parties agreed *"… that the '900-foot' aquifer* (aka the Deep Aquifers) *should be managed to provide safe, sustained use of the water resource, and to preserve to MCWD the continued availability of water from the '900-foot' aquifer."*

Deep Aquifers have also showed a steeper decreasing trend than the lower portion of the Deep Aquifers over the past 15 years.

- Similar declines in groundwater elevations are observed in Deep Aquifers wells located in the adjacent 180/400-Foot Aquifer Subbasin near Cooper Road and Blanco Road. Figure 5-15 shows long-term hydrographs for wells located near the Monterey-180/400-Foot Aquifer Subbasin boundary. As shown on these hydrographs, groundwater elevations in wells located near Cooper Road and Blanco Road have declined more than 5 ft/year over the past 15 years.
- The observed decline in groundwater elevations in the Deep Aquifers is the result of increased groundwater production from the Deep Aquifers in the Monterey and 180/400 Foot Aquifer Subbasins. Information collected by the MCWRA (Figure 5-16) shows that groundwater production from the Deep Aquifers increased from approximately 2,500 AFY in 2008 to over 10,000 AFY in 2019 (MCWRA, 2020). Approximately 30 new Deep Aquifers production wells were permitted and constructed within the 180/400 Foot Aquifer Subbasin during this period (MCWRA, 2020). Groundwater pumping from the Deep Aquifers within the Monterey Subbasin is limited to MCWD's municipal production, which has been relatively stable at quantities ranging from 2,000 AFY to 2,500 AFY since 1990 and is well within the limit established within the Annexation Agreements with MCWRA as detailed in Chapter 3. Increases in Groundwater production from the Deep Aquifers are primarily occurring in the 180/400-Foot Aquifer Subbasin immediately north of the Monterey Subbasin. The 180-Foot and 400-Foot Aquifers are seawater intruded in this area and no alternative water source is available, i.e. it is outside the existing Castroville Seawater Intrusion Project (CSIP) service area.

#### *5.1.3.2 Corral de Tierra Area*

Groundwater elevations have been monitored in several wells, which are screened in the El Toro Primary Aquifer System in the Corral de Tierra area since 1960. Of these wells, a few wells show groundwater elevation declines of up to 60 to 80 feet. On average, long-term groundwater elevations declines are 40-50 feet (Figure 5-17) (GeoSyntec, 2007).

According to the 2007 *El Toro Groundwater Study* report, the majority of long-term hydrographs exhibit a downward trend in groundwater elevations with an average rate of decline of -0.6 ft/yr (GeoSyntec, 2007). Since 1999, some hydrographs show larger rates of groundwater elevation decline, averaging 1.8 feet per year (GeoSyntec, 2007). The Laguna Seca area, which is in the Seaside Subbasin west of the Corral de Tierra subarea, shows similar groundwater elevation declines and has been demonstrated to be hydrogeologically connected to the El Toro area (GeoSyntec, 2007; Hydrometrics, 2009).

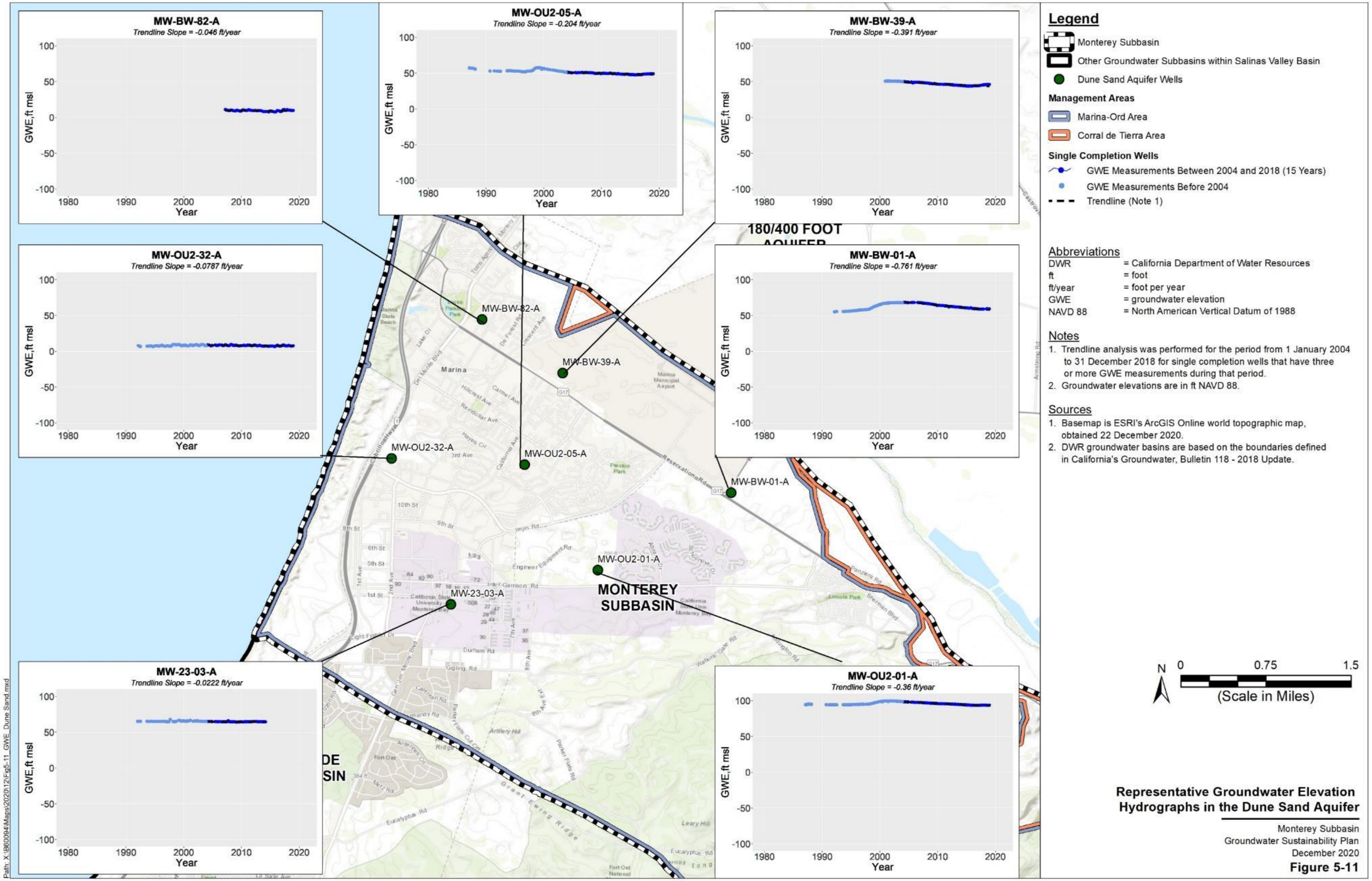



**Figure 5-11. Representative Groundwater Elevation Hydrographs in the Dune Sand Aquifer**

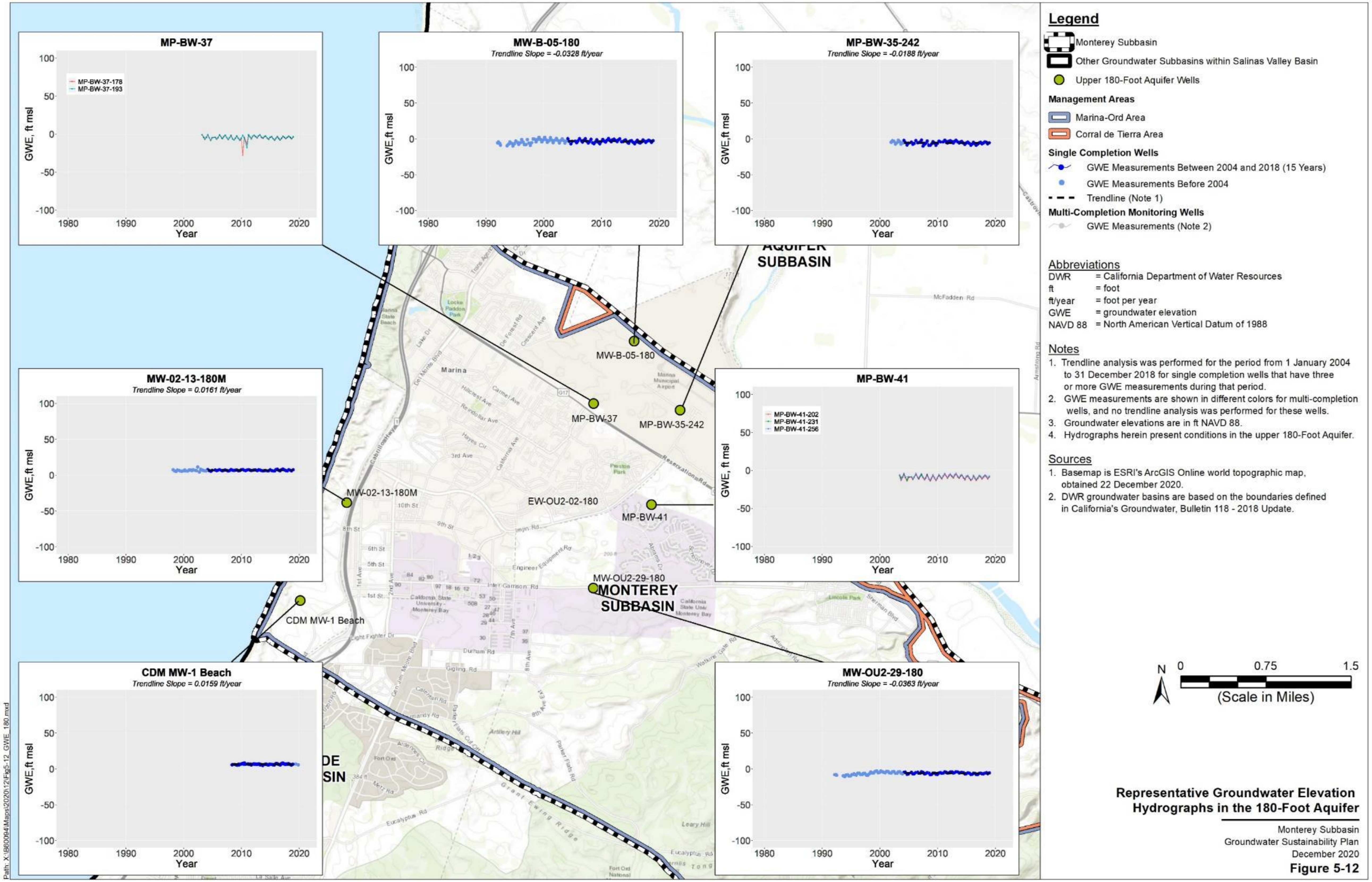



**Figure 5-12. Representative Groundwater Elevation Hydrographs in the 180-Foot Aquifer**

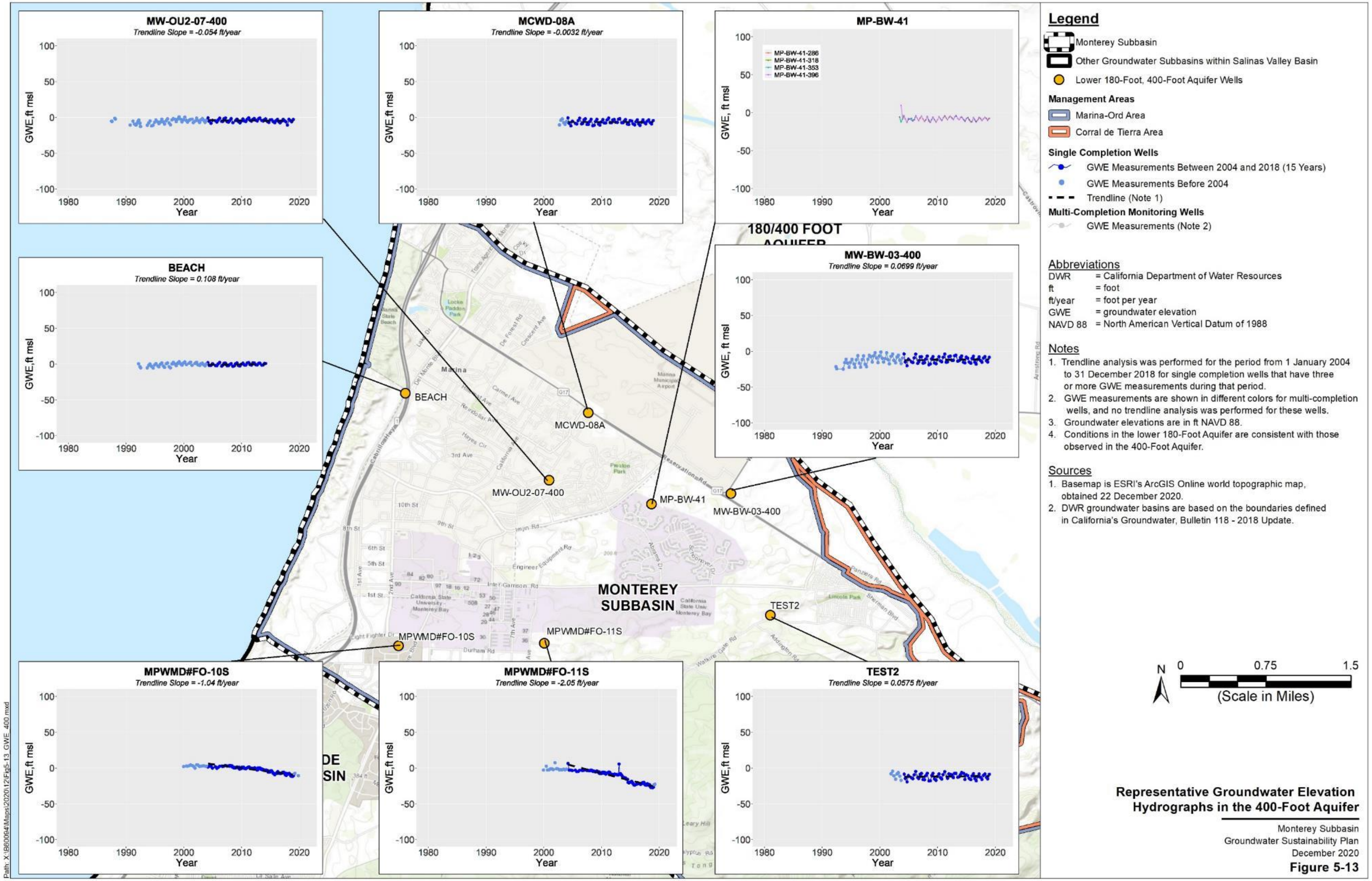



**Figure 5-13. Representative Groundwater Elevation Hydrographs in the 400-Foot Aquifer**

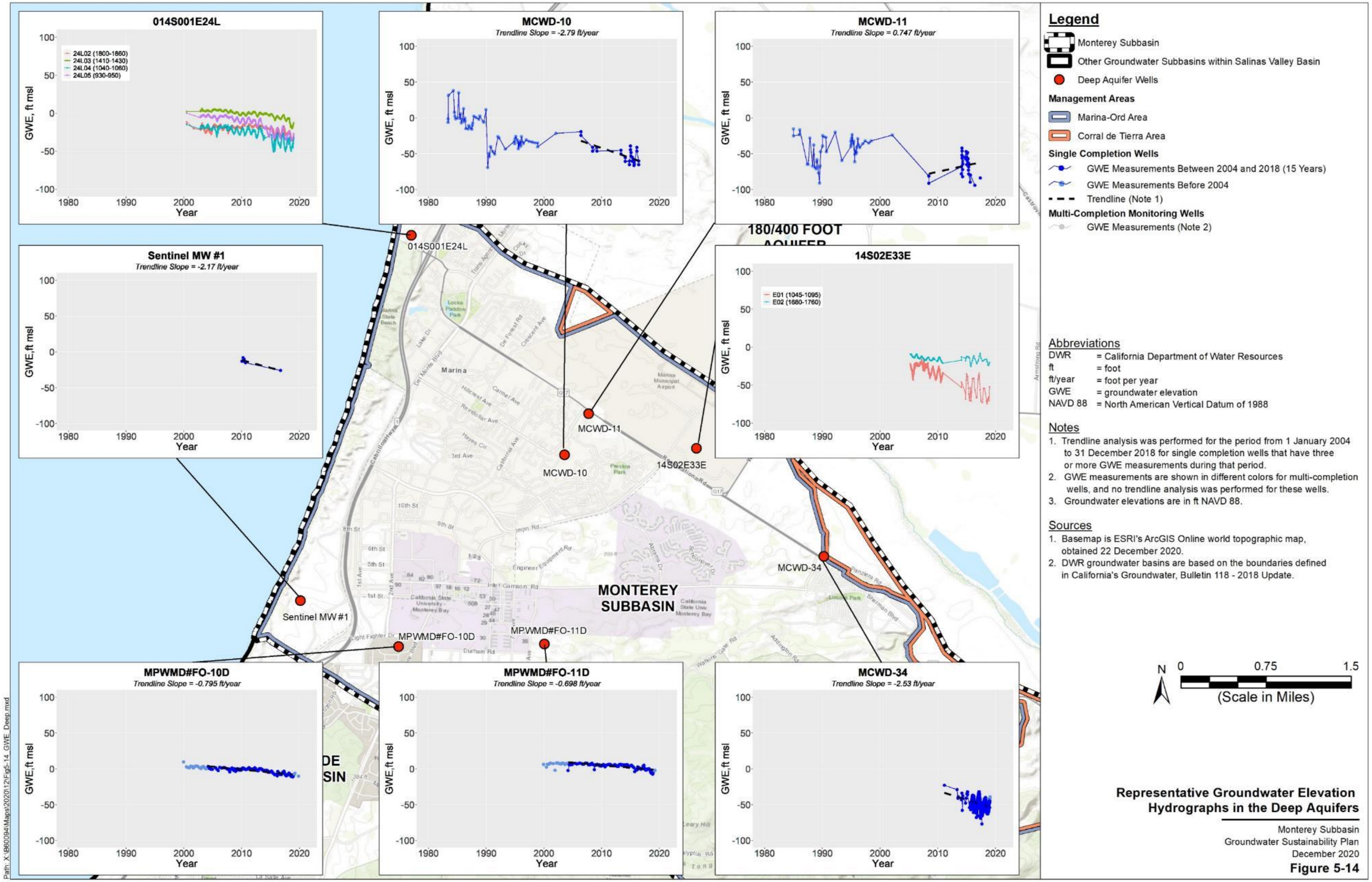



**Figure 5-14. Representative Groundwater Elevation Hydrographs in the Deep Aquifers**

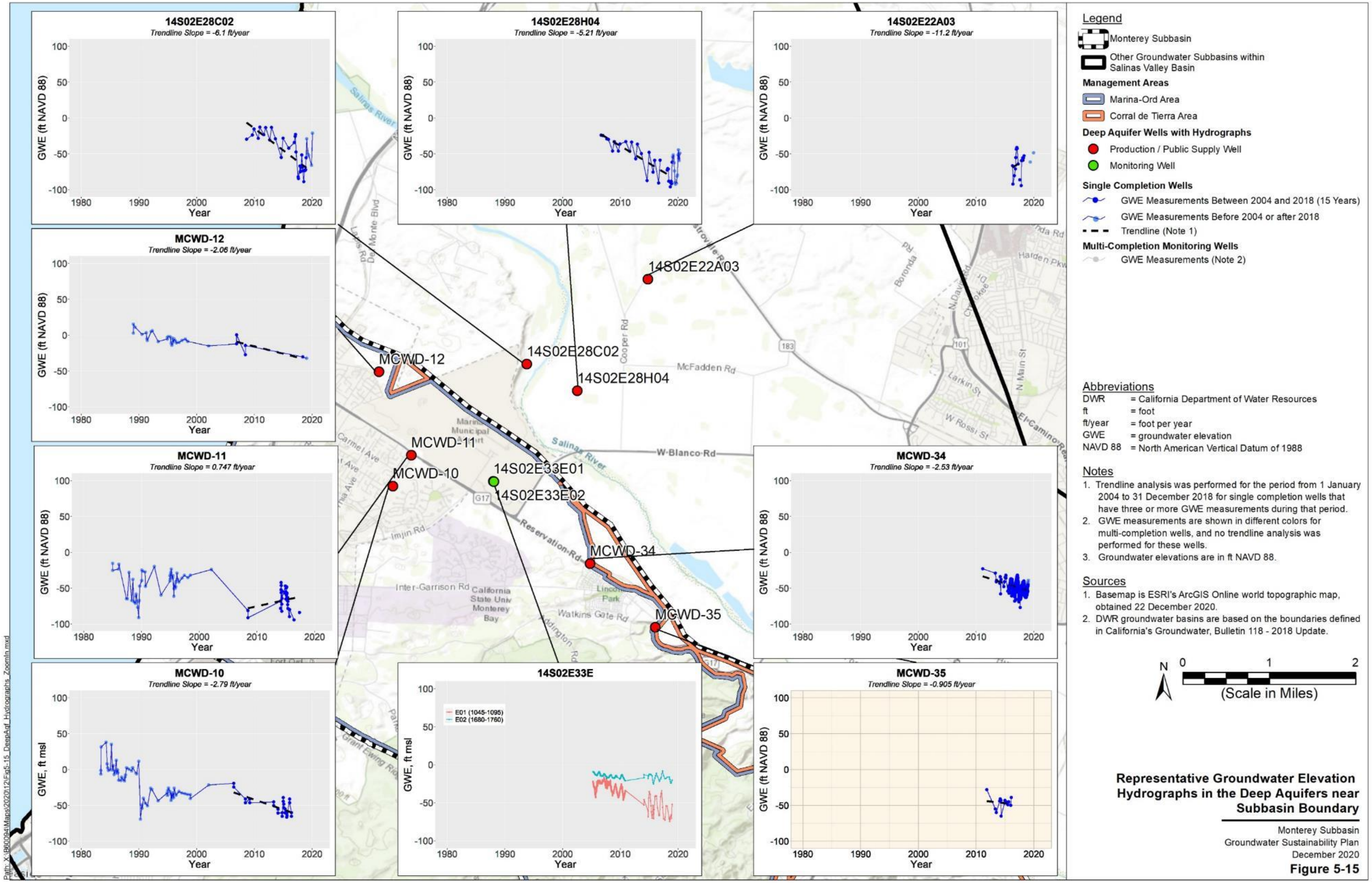
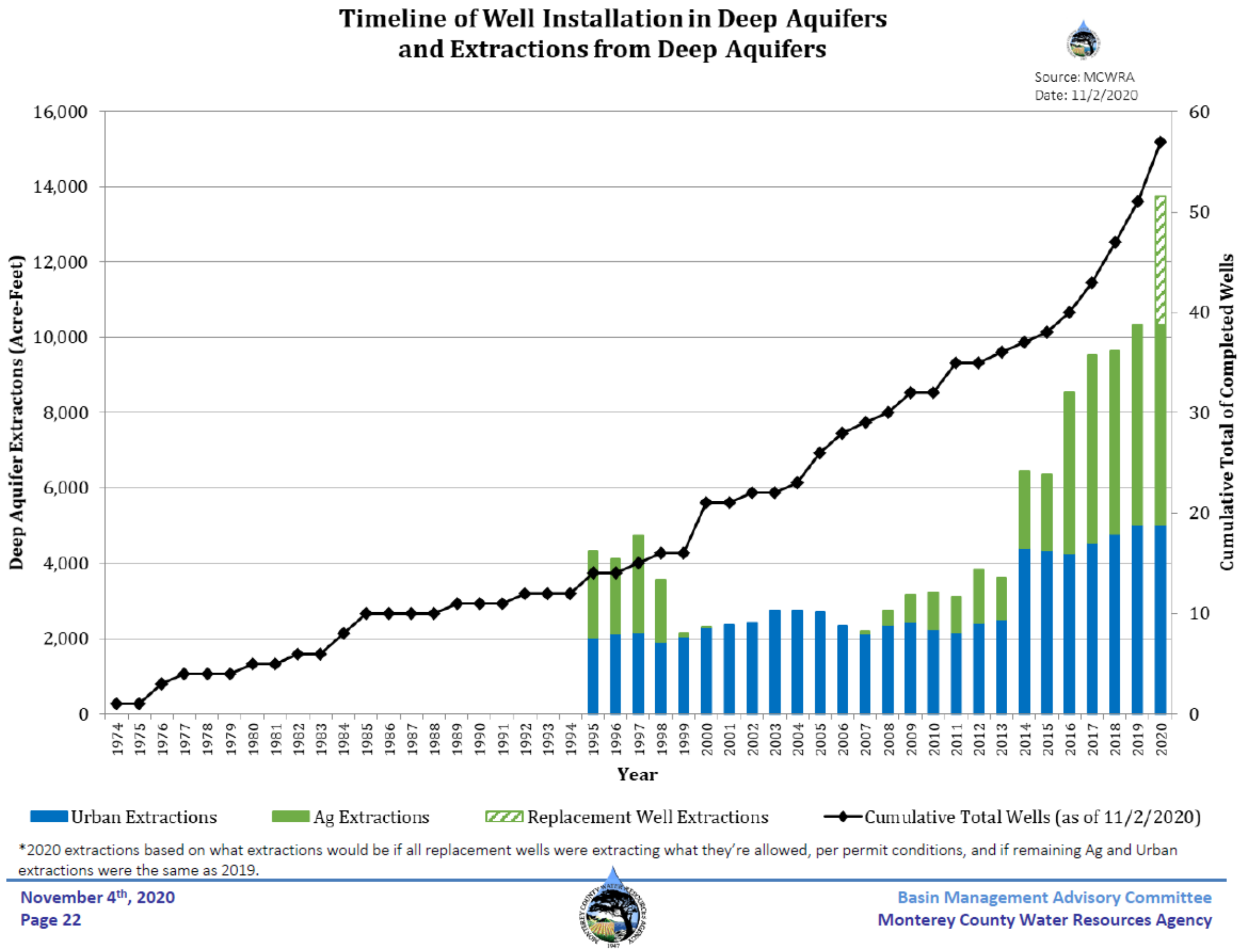



**Figure 5-15. Representative Groundwater Elevation Hydrographs in the Deep Aquifers near Subbasin Boundary**

**Figure 5-16. Timeline of Well Installation in Deep Aquifer and Extraction from Deep Aquifers**




Note: Municipal groundwater production shown post 2014 includes production by MCWD within the Monterey Subbasin as well as production by municipal and industrial groundwater users within the 180/400-Foot Aquifer Subbasin. Area is defined by Groundwater Extraction Management System (GEMS) ordinance and represents all extractions reported from the Deep Aquifers, most of which is within the 180/400-Ft Aquifer Subbasin, not the Monterey Subbasin.

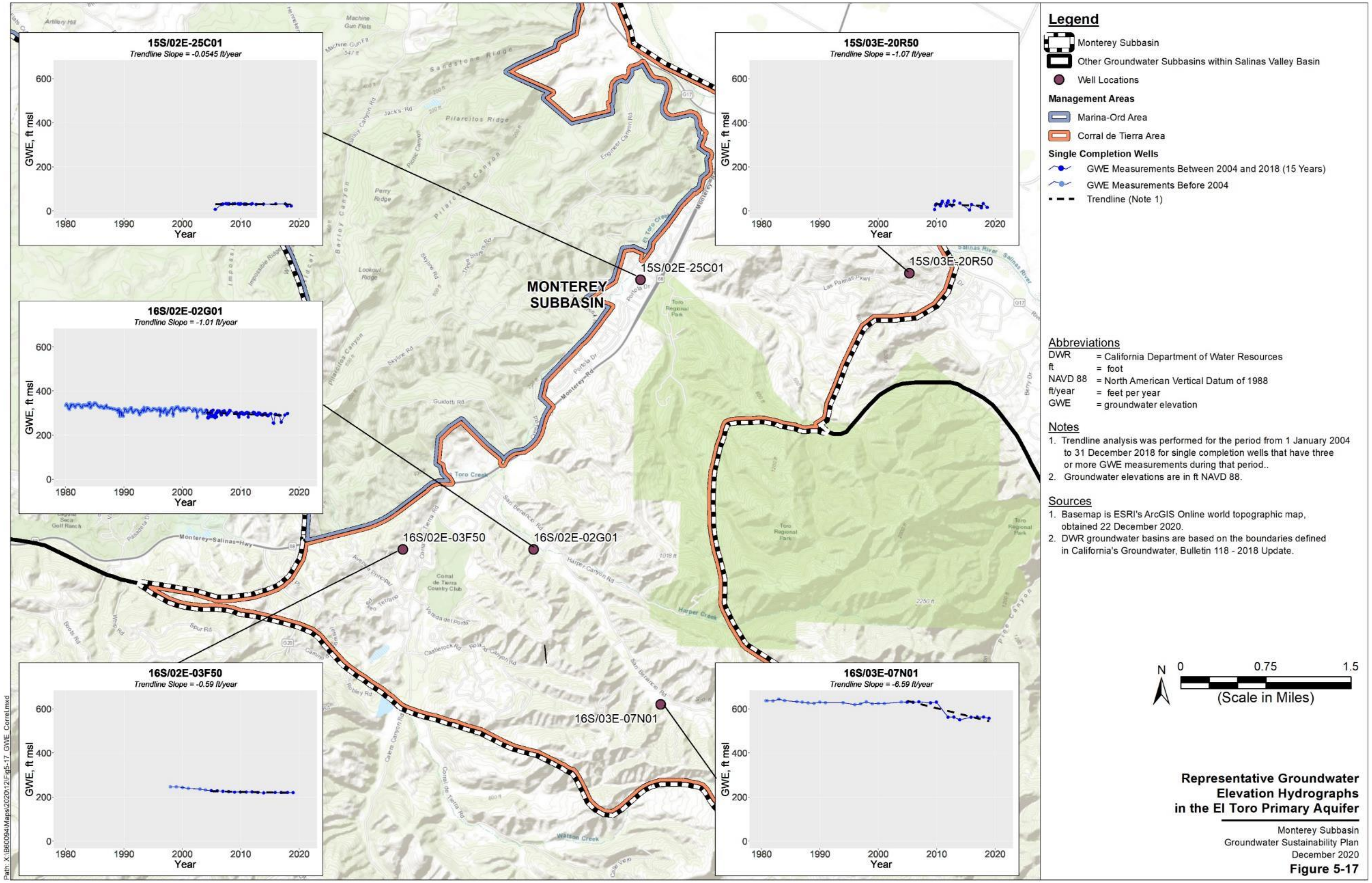
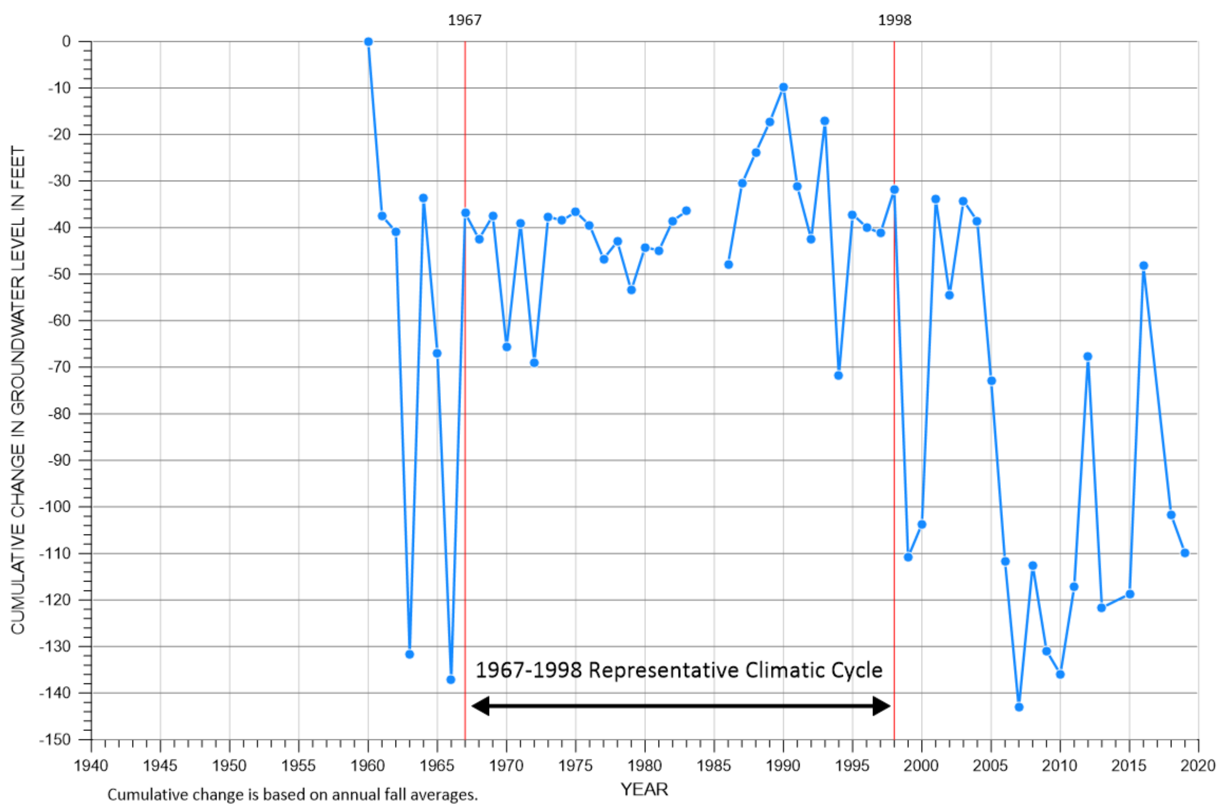



**Figure 5-17. Representative Groundwater Elevation Hydrographs in the El Toro Primary Aquifer**

Another way of looking at temporal groundwater elevation trends is shown on Figure 5-18, which presents a graph of cumulative groundwater elevation change for the El Toro Primary Aquifer System. The graph of cumulative change in groundwater elevation is based on averaged change in Fall groundwater elevations for designated wells in the subarea each year. MCWRA uses Fall groundwater elevations because these measurements are taken after the end of the irrigation season and before seasonal recharge from winter precipitation increases in groundwater levels. The cumulative groundwater elevation change plot is therefore an estimated average hydrograph for wells in the subarea. Although this plot does not reflect the groundwater elevation change at any specific location, it provides a general illustration of how the average groundwater elevation in the subarea changes in response to climatic cycles, groundwater extraction, and water-resources management at the subbasin scale.

The graph of cumulative elevation change and the specific hydrographs presented in Appendix 8-B show a long-term decline in groundwater elevations in the Subbasin over time.

**Figure 5-18. Cumulative Groundwater Elevation Change for the Corral de Tierra area**




## 5.1.4 Vertical Hydraulic Groundwater Gradients

Downward vertical hydraulic gradients exist in many portions of the Subbasin. These downward vertical gradients are caused by areal surface recharge, groundwater extraction from deeper aquifers, and laterally extensive aquitards, which exist in the Marina-Ord Area. These vertical hydraulic gradients can impact the magnitude and direction of groundwater flow between principal aquifers and increase the potential for downward migration of highly saline water in seawater intruded areas, if pathways exist between aquifers.

Evaluation of vertical gradients can be accomplished by examination of groundwater elevations measured in collocated wells screened in different aquifers. This approach requires water level information from wells that: (a) have known well construction information, (b) are only screened in one Principal Aquifer, (c) have contemporaneous measurements (i.e., water levels measured at least in the same year and season), and (d) are in close spatial proximity to each other. It is important to note that a difference in groundwater elevation between principal aquifers does not, in and of itself, establish a vertical flow.

**Figure 5-19** shows four sets of wells located in the central portion of the Marina-Ord Area and one set of wells located near the coast that meet the identified criteria.  The hydrographs for each set of wells illustrate the difference in groundwater elevations between Principal Aquifers. In the central Marina-Ord Area, groundwater elevations are approximately 70 ft lower in 180-Foot Aquifer and 400-Foot Aquifer than in Dune Sand Aquifer. Groundwater elevations are approximately 60 ft lower in Deep Aquifers than in the 180-Foot and 400-Foot Aquifers. Near the Monterey Coast, there is no appreciable groundwater elevation difference between the Dune Sand Aquifer and the (upper) 180-Foot Aquifer.

**Figure 5-20** shows estimated vertical gradients between the 400-Foot Aquifer and the Deep Aquifers in the Fall of 2017.  These estimated vertical gradients are calculated based on the difference groundwater elevation contours for the 400-Foot Aquifer and Deep Aquifers shown on Figure 5-3 and Figure 5-4, respectively. As shown on Figure 5-20, groundwater elevations in the Deep Aquifers are 20 to 60 ft lower than those in the 400-Foot Aquifer in the northwestern portion of the Subbasin where the lower 180-Foot/400-Foot Aquifer is seawater intruded.

While many wells in the Corral de Tierra area are screened in both the Paso Robles Formation and the Santa Margarita Sandstone, some wells are screened more in the Paso Robles Formation and some are screened more in the Santa Margarita Sandstone. Downward vertical hydraulic gradients have been recorded in the Laguna Seca subarea of the adjacent Seaside Subbasin (Yates, 2002). Therefore, there is an expectation that downward vertical gradients exist between the Paso Robles Formation and the Santa Margarita Sandstone within the El Toro Primary Aquifer System (GeoSyntec, 2007). Figure 5-21shows hydrographs between wells screened exclusively in the Paso Robles Formation (shallow) and the Santa Margarita Sandstone (deep) in the Corral de Tierra area near the Laguna Seca region. There is an approximate 75-foot difference in the water levels between the two water-bearing formations. Due to the sediments that comprise these water-bearing formations, there is likely downward vertical flow between the formations as a result of these gradients.

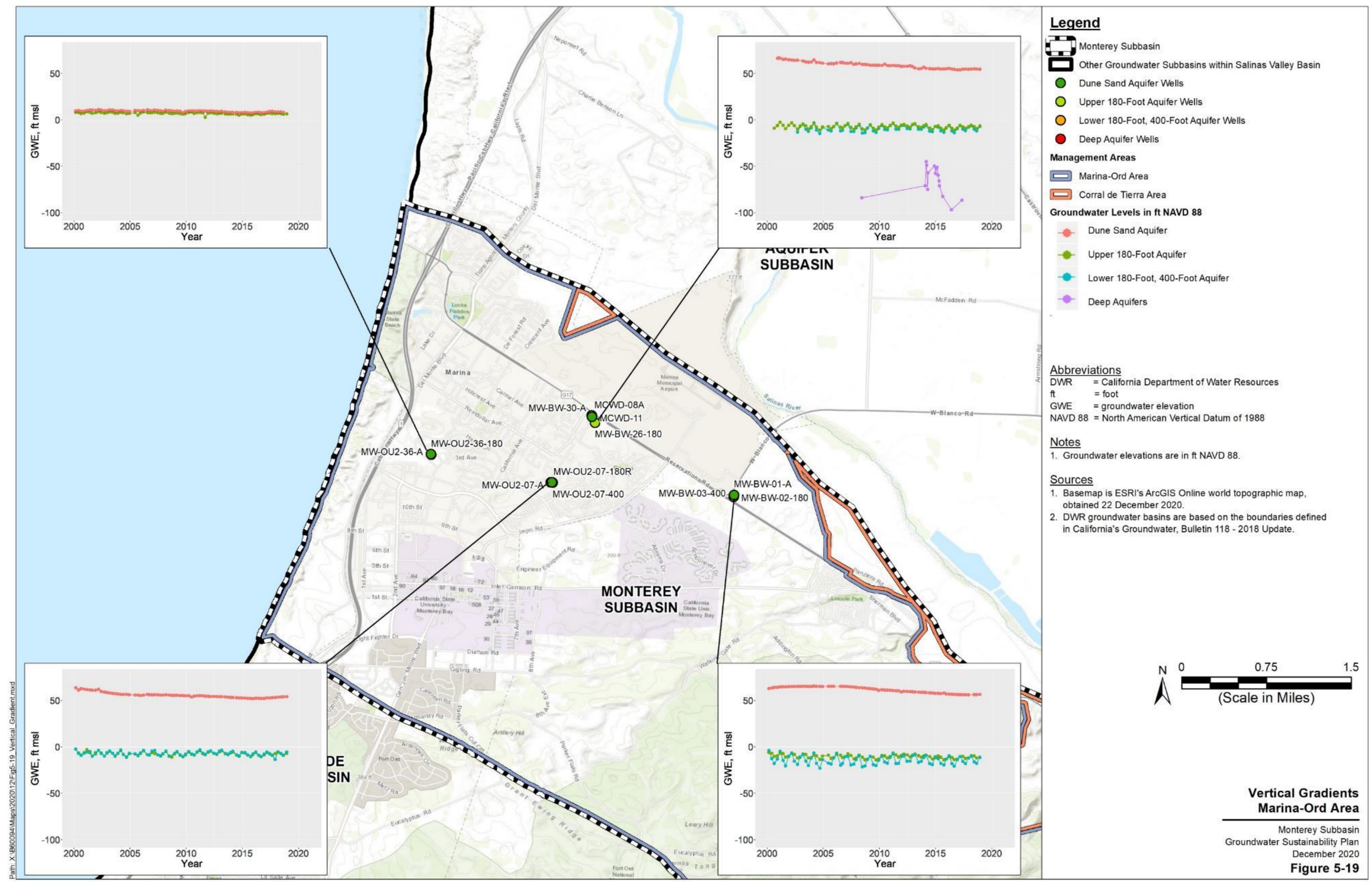



**Figure 5-19. Vertical Gradients, Marina-Ord Area**

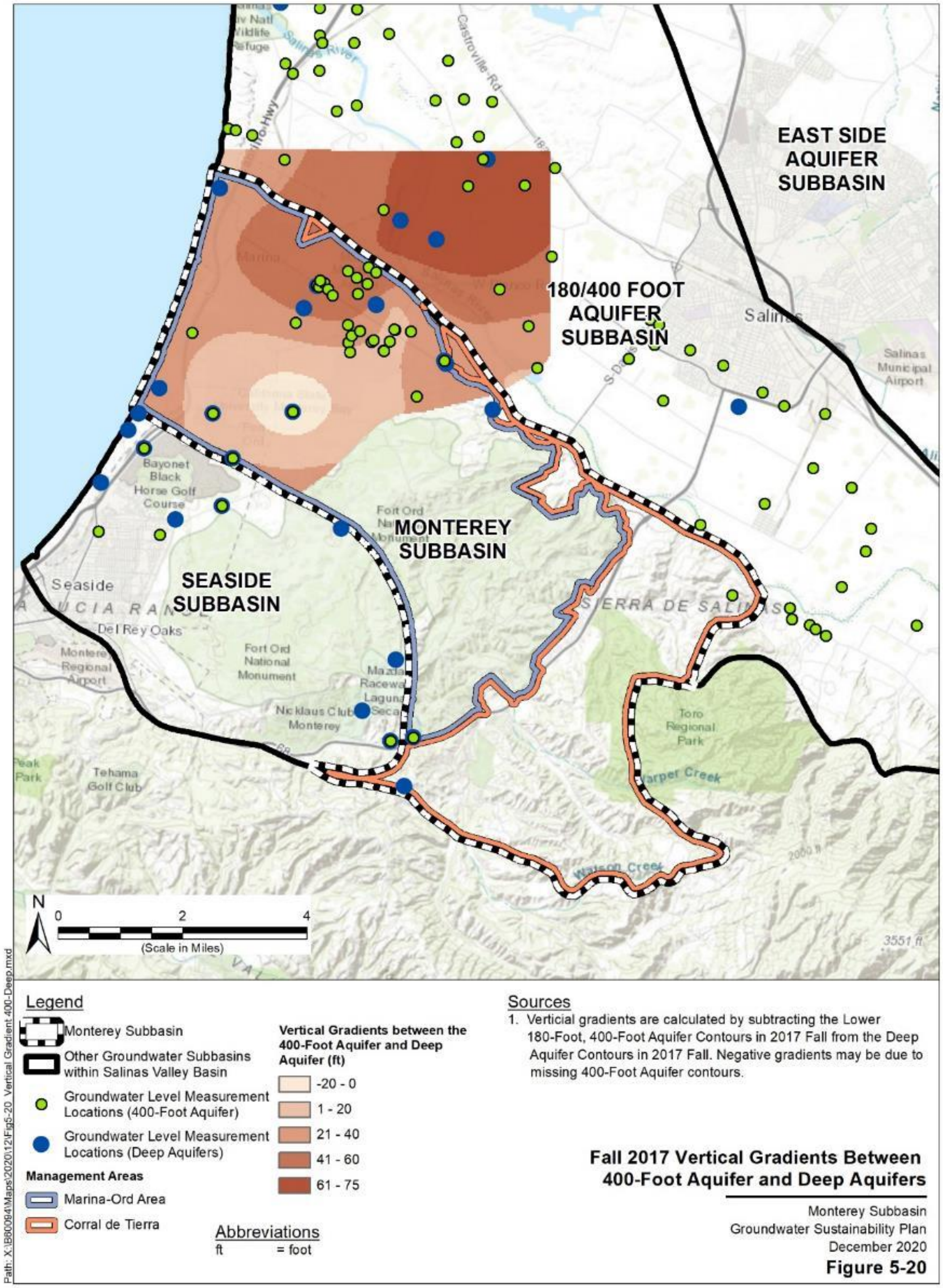



**Figure 5-20. Fall 2017 Vertical Gradients Between 400-Foot Aquifer and Deep Aquifers**

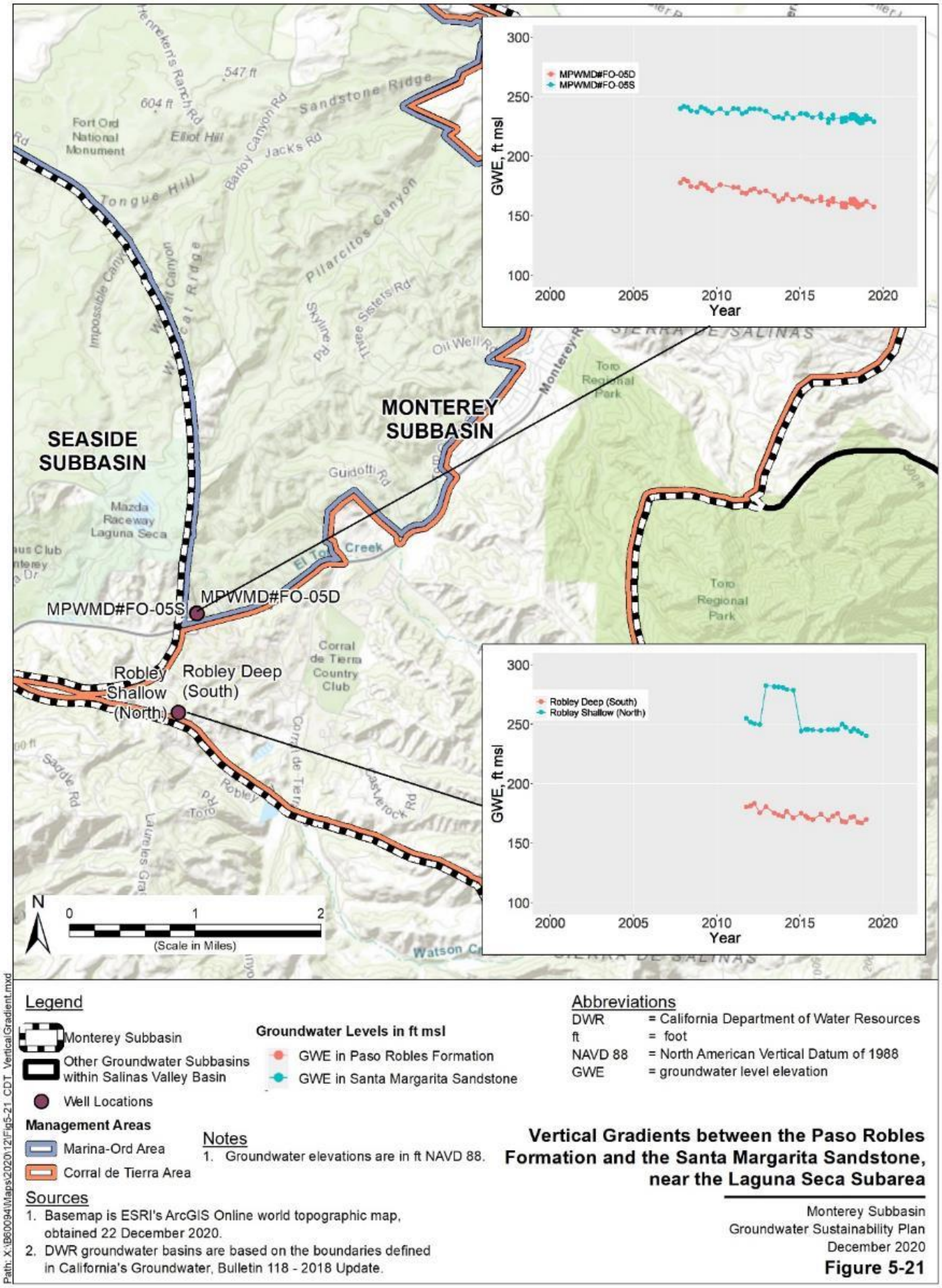



**Figure 5-21 Vertical Gradients between the Paso Robles Formation and the Santa Margarita Sandstone, near the Laguna Seca Subarea**

## 5.2 Change in Groundwater Storage

Estimate change in storage for the Monterey Subbasin were simulated for the historical period (i.e. WY 2004-2018) using the numerical model developed for the Monterey Subbasin. A description of the numerical model and results are detailed in Chapter 6. Changes of storage estimates for the historical period are detailed in Appendix 6A and summarized blow.

Annual average change in storage within the Monterey Subbasin was estimated to be -4,434 AFY during WY 2004-2018. The cumulative change in storage over this 15-year period was estimated to be -66,517 AF. Seawater inflow to the Monterey Subbasin across the ocean boundary during the historical period is presumed to leave the subbasin across the 180/400-Foot Aquifer Subbasin boundary, given that there has been no observed expansion of the seawater intrusion front during the historical period (Section 5.3.4).

Change of storage estimates were additionally calculated for each of the management area water budget zones (WBZs)[3]. Within the Marina-Ord Area WBZ, annual average change in storage over the historical period was estimated at -1,632 AFY for a cumulative change in storage of -24,478 AF. The majority of this loss occurred within the 400-Foot and Deep Aquifers, consistent with recent groundwater elevation trends described in Section 5.1.3 above. Within the Corral de Tierra Area WBZ, the annual average change in storage over the historical period was estimated to be-2,803 AFY for a cumulative change in storage of -42,039 AF.

There are inherent uncertainties using numerical models as they can only approximate physical systems and have limitations in how they compute data. The uncertainty associated with the model estimates is explored further in Section 6.7. However, the groundwater model selected to perform this analysis represents the best available tool for estimating water budget and change in storage. A detailed discussion of data input and assumptions into the Monterey Subbasin Groundwater Flow Model (MBGWFM) is included in Sections 6.1 and 6.2 and Appendix 6B. As additional groundwater elevation, aquifer properties, and groundwater extraction data become available, they will be used to refine representation of these aquifers as part of future modeling efforts.

## 5.3 Seawater Intrusion

Groundwater overdraft in the larger Salinas Valley Basin has resulted in landward groundwater gradients near the coast and created an influx of highly saline water in the coastal aquifers. Seawater intrusion has been documented in the Salinas Valley Basin since the 1940s (DWR, 1946). Within the Monterey Subbasin, seawater intrusion has been documented in the northern portion of the lower 180-Foot and 400-Foot Aquifers.

[3] As described in Chapter 6, the Marina-Ord Area WBZ includes the Marina-Ord Area as well as well as the Reservation Road portion of the Corral de Tierra Area, as they share the same principal aquifers; the Corral de Tierra Area WBZ includes the main portion of the Corral de Tierra Area underlain by the El Toro Primary Aquifer System.

The negative impact of seawater intrusion on local water resources and the agricultural economy has been the primary motivation for many studies dating back to 1946 (DWR, 1946). MCWRA and others have implemented a series of engineering and management projects including well construction moratoriums, developing the Castroville Seawater Intrusion Project (CSIP) system, and implementing the Salinas Valley Water Project (SVWP), among other actions to halt seawater intrusion. Although those actions have managed to slow the advance of intrusion and reduce its impacts, seawater intrusion remains an ongoing threat.

### 5.3.1 Data Sources

Water quality data discussed in this section was obtained from various local monitoring agencies including MCWD, MCWRA, Fort Ord, MPWMD, and the Seaside Groundwater Basin Watermaster. These data are augmented by results from two airborne electromagnetic (AEM) surveys conducted by MCWD in 2017 and 2019.

#### *5.3.1.1 Water Quality Data*

The extent and advancement of seawater intrusion within the Subbasin has been monitored by local monitoring agencies. The following TDS, chloride, as well as specific conductivity data are analyzed herein:

- Water quality data collected by MCWRA and MPWMD;
- Water quality data collected by MCWD in December 2018 from MCWD wells and Fort Ord monitoring wells (EKI, 2019).

These water quality data are shown on Figure 5-24 and discussed in detail in Section 5.3.3.

#### *5.3.1.2 Geophysical Data*

Geophysical data considered in this GSP include AEM data obtained for the northern Salinas Valley and induction logging data obtained from Sentinel Wells installed along the Monterey and Seaside Subbasin coastline.

In 2017 and 2019, MCWD retained geophysical consultants (Aqua Geo Framework) and Stanford University researchers to obtain and analyze AEM data within the northern Salinas Valley Basin (Stanford/Aqua Geo Frameworks; Aqua Geo Frameworks, 2019). During these surveys, a helicopter carrying electronic geophysical equipment surveyed resistivity of subsurface geology over an approximately 15-mile by 7-mile area along the coastal 180/400 Foot Aquifer and Monterey Subbasins. The studies' goal was to evaluate the understanding of the hydrostratigraphy in the study area and to interpret the distribution of groundwater quality indicated by available well data. A first round of AEM data were collected in April 2017, shortly after the 2014-2016 drought. A second round of AEM data were collected in May 2019, which is more representative of a wetter hydrologic condition. The data collected during each round of AEM were "inverted" to develop a three-dimensional picture of the distribution of electrical resistivity.

The AEM survey measures the resistivity of a volume of subsurface material composed of sediments containing air and/or water (Stanford/Aqua Geo Frameworks, 2018). While measurement of the electrical resistivity of the water alone (typically reported as the inverse parameter, electrical conductivity) can be a direct indicator of the salinity of the water (i.e., the more salts in the water, the lower the electrical resistivity), the electrical resistivity of a volume of subsurface material is determined not just by the salinity of the water, but is also affected by the texture and mineralogy of the sediments and the volume of water present. Very simply, increasing the amount of clay, the amount of water, and/or the salinity of the water all decrease the electrical resistivity.

A part of the studies' scope was to investigate the relationship between inverted AEM data and water quality. The following interpretation of AEM data have been experimentally developed for the study area.

**Table 5-1. Experimental Interpretation of AEM Resistivity Data in the Northern Salinas Valley**

| **TDS Concentration in Groundwater** | **AEM Resistivity** Within general or unknown aquifer materials (Stanford/Aqua Geo Frameworks, 2018) | **AEM Resistivity** Within the sandy/gravelly 180-Foot and 400-Foot Aquifers (Aqua Geo Frameworks, 2019) |
|---|---|---|
| Greater than 10,000 mg/L | Less than 5 ohm/cm | Less than 7.2 ohm/cm |
| Less than 3,000 mg/L | Greater than 25 ohm/cm | Greater than 13.2 ohm/cm |

The Stanford study found that very high resistivity (greater than 25 ohm/cm) or very low resistivity (smaller than 5 ohm/cm) are indicative of fresh groundwater and high salinity groundwater, respectively. Moderate AEM resistively in the range of 5 to 25 ohm/cm can be indicative of either higher salinity or higher amount of clay in subsurface materials, thus the exact water quality associated with these resistivity values is more difficult to discern. In the known extents of sandy and gravelly 180-Foot and 400-Foot Aquifers, Aqua Geo Frameworks (AGF) has developed an experimental relationship whereby AEM resistivity of greater than 13.2 ohm/cm and less than 7.2 ohm/cm are indicative of fresh groundwater and high salinity groundwater, respectively.

The AEM surveys have found that high salinity groundwater as a result of seawater intrusion exists within the lower 180-Foot Aquifer and 400-Foot Aquifers of the Monterey Subbasin. This volume of high salinity groundwater is overlain by fresh groundwater in the Dune Sand and upper 180-Foot Aquifers. The results of the AEM study are consistent with water quality data collected within the Subbasin (EKI, 2019). No significant difference was found between seawater intrusion conditions in 2017 and 2019 within the Subbasin.

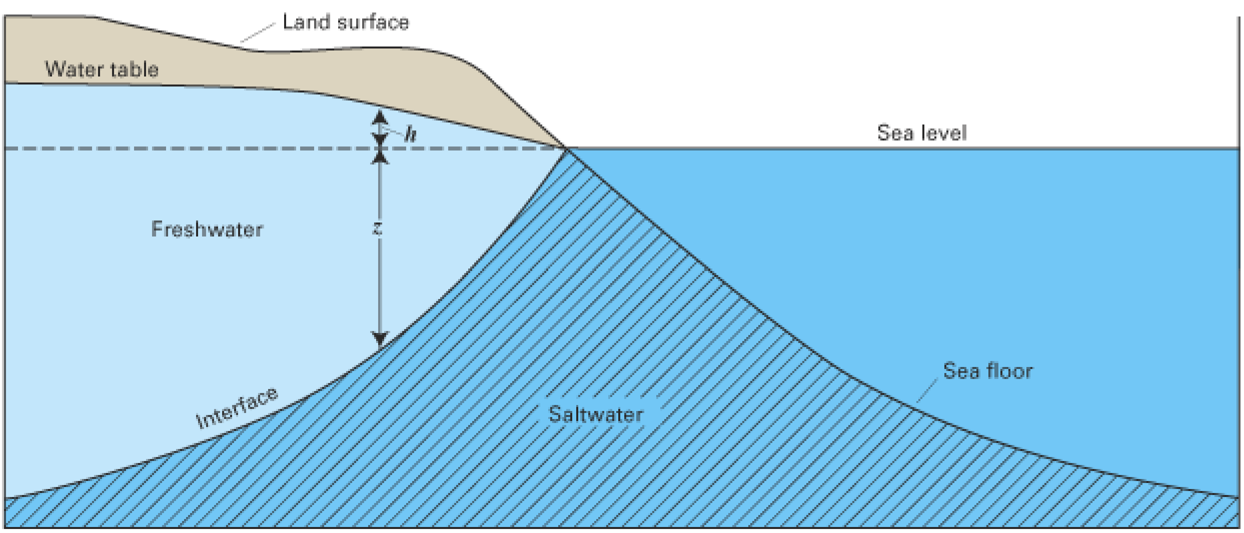
Induction logging within a well measures the fluid conductivity within the adjacent formation. Although this method does not provide exact measurements of water quality, it can be used to monitor change in conductivity (i.e., groundwater salinity) over time. The Seaside Basin Watermaster constructed and maintains four Sentinel Wells along the coast to detect potential seawater intrusion. The northern-most well, SBMW-1, is located within the Monterey Subbasin. The Watermaster conducts semi-annual induction logging within these wells. During baseline monitoring of SBMW-1 in 2007, it has been documented that very high conductivities indicative of saline groundwater were observed in depths from 125 feet to approximately 350-400 feet (Feeney, 2007). There has been no significant change in salinity observed in this well since 2007 (Montgomery & Associates, 2019).

### 5.3.2 Defining Seawater Intrusion

Coastal aquifers usually contain two sets of flow going into opposite directions: lower density freshwater flowing seaward and higher density seawater flowing inland. When groundwater levels in aquifers connected to the ocean fall to near or below sea level, flows across the ocean/land boundary become predominantly onshore flows (Barlow, 2003). As higher density seawater flows inland, it forms a seawater wedge beneath the less dense fresh groundwater until the water table achieves equilibrium, as shown on Figure 5-22.

The freshwater depth above sea level and the freshwater depth below the sea level in the wedge are related to each other through the Ghyben-Herzberg Relation, which states that for every foot of freshwater above sea level there is approximately 40 feet of freshwater below sea level (Barlow, 2003). For a given depth within the subsurface, therefore, the potentiometric head must be at least 1/40 of that depth above sea level in order for freshwater to be present at that depth. For example, for freshwater to be present within the 180-Foot Aquifer and 400-Foot Aquifer (i.e. with bottom depths of approximately -250 ft NAVD88 and -500 ft NVAD88, respectively), the potentiometric surface in those aquifers needs to be maintained at an elevation of at least 6.3 ft NVAD88 and 12.5 ft NAVD88, respectively. In a complexly layered aquifer system like the Salinas Valley Basin, each aquifer may have its own seawater wedge, with a seawater front at different horizontal distances from the shoreline, depending on each aquifers' relative hydraulic connection to pumping wells and the Pacific Ocean (Yates and Wiese, 1988).

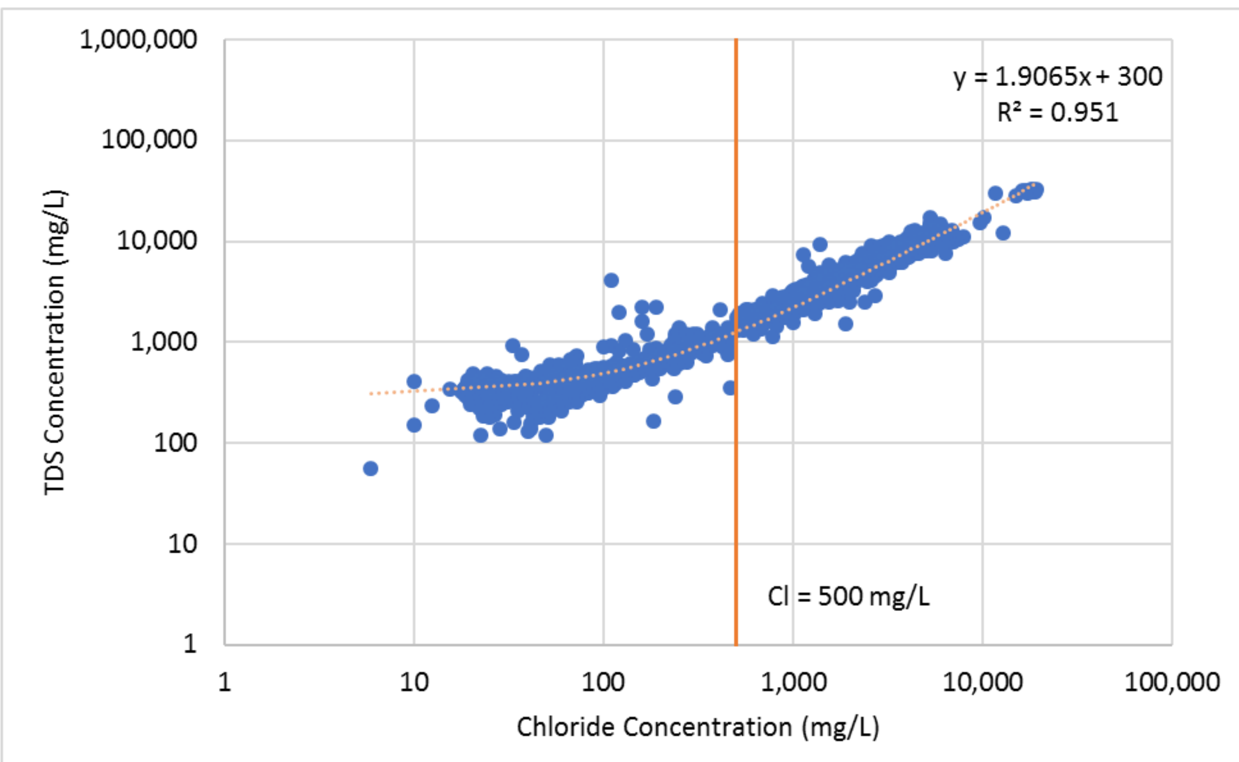
**Figure 5-22. Ghyben-Herzberg Relation (Barlow, 2003)**



The definition of seawater intrusion is generally based on a TDS or chloride concentration threshold and is dependent on local beneficial uses and groundwater protection strategies. In the larger Salinas Valley Basin, MCWRA has defined the seawater intrusion threshold as 500 mg/L of chloride. This chloride concentration is significantly lower than the 19,000 mg/L chloride concentration typical of seawater, but it represents a concentration that impacts use of the water. Additionally, groundwater in the Marina-Ord aquifers has low natural TDS generally less than 500 mg/L and the primary source of salinity in this area is seawater intrusion. Therefore, this GSP adopts the seawater intrusion threshold as 500 mg/L of chloride, or 1,000 mg/L of TDS as a surrogate where chloride data are unavailable.

TDS has been identified as a surrogate for chloride to define seawater intrusion due to the scarcity of actual chloride measurements within the subbasin and the excellent correlation between these two parameters in the Marina-Ord aquifers. Groundwater in the Marina-Ord aquifers has low natural TDS generally less than 500 mg/L and the primary source of salinity in this area is seawater intrusion. The strong correlation between these water quality parameters within the seawater intruded lower 180-Foot/400-Foot Aquifer is shown on Figure 5-23 below. Appendix 5-A further examines this correlation and establishes a quantitative relationship to allow conversion between TDS and chloride concentrations detected in this aquifer.

**Figure 5-23. Relationship Between TDS and Chloride Concentrations in the Lower 180-Foot, 400-Foot Aquifer**




It should be noted that the seawater-affected groundwater quality may well be sufficient for many beneficial uses. In other words, while the definition of seawater intrusion front as the 500 mg/L chloride threshold (or 1,000 mg/L of TDS as a surrogate) is a useful guideline for identifying when some seawater intrusion affect may be detected, this does not necessarily mean that the groundwater within the affected region is no longer suitable for current or potential beneficial uses. Specifically, the following beneficial use standards on TDS apply to groundwater within the seawater intruded area of the Subbasin:

- The State of California has adopted an upper Secondary Maximum Contaminant Level (SMCL) for TDS of 1,000 mg/L, and a short-term maximum SMCL of 1,500 mg/L for drinking water.
- Under SWRCB Resolution 88-63, the state considers all groundwater containing TDS at concentrations less than 3,000 mg/L as having a potential beneficial use as a domestic and municipal supply. This Resolution is adopted as part of the RWQCB's Water Quality Protection Plan for the region.
- The Federal Clean Water Act defines groundwater containing less than 10,000 mg/L TDS as an Underground Source of Drinking Water.
- SWRCB Resolution 68-16, also known as the Antidegradation Policy, requires that the existing high quality of waters be maintained to the maximum extent possible, and allows degradation only if it is consistent with maximum benefit to the people of the state, will not unreasonably affect present and potential beneficial uses, and will not result in water quality lower than applicable standards.

### 5.3.3 Seawater Intrusion Maps and Cross-sections

Figure 5-24 shows recent (post-2015) TDS concentrations in each of the coastal aquifers. As shown on Figure 5-24, TDS concentrations measured in the Dune Sand, upper 180-Foot, and Deep Aquifers monitoring locations are generally below 1,000 mg/L, indicating that there is no or minimal seawater intrusion in these aquifers. In the lower 180-Foot and 400-Foot Aquifers, TDS concentrations of over 10,000 mg/L are observed up to four miles inland near the northern Monterey Subbasin boundary.

As shown on Figure 5-25, cross-sections A-A' and B-B' (Figure 5-26 and Figure 5-27) run perpendicular to the coastline and show relevant TDS data (measured at designed well screen intervals) and 2019 AEM survey data along these transects. Cross-section B-B' is located within the Monterey Subbasin; however, AEM data along this cross-section are sporadic due to the absence of AEM data in urban areas where high density of utilities interferes with AEM data collection. Cross-section A-A' runs immediately north of the Monterey Subbasin, and provides insight regarding the vertical delineation of seawater intrusion within the coastal areas of the Monterey Subbasin.

TDS and AEM data shown on these cross-sections confirm that seawater intrusion in the Monterey Subbasin primarily exists in the lower 180-Foot Aquifer and 400-Foot Aquifer, whereas groundwater in the Dune Sand and upper 180-Foot Aquifers remains fresh. TDS concentrations are dramatically different in different depths of the multi-completion wells (e.g., MP-BW-37), and the highest TDS concentration occurs in approximately 360 to 400 feet below ground surface (ft bgs). It appears that seawater intrusion in these two aquifers forms a unified intrusion wedge, due to the discontinuity of the 180/400-Foot Aquitard near the coast. The data are consistent with the Ghyben-Herzberg Relation, which accounts for the downward movement of high-density seawater, overlain by lighter freshwater.

Based on available TDS and AEM data, Figure 5-28 depicts the estimated extent of seawater intrusion within the Monterey Subbasin. As shown on Figure 5-28, seawater intrusion within the Monterey Subbasin extends as far as four miles inland. This estimated extent of seawater intrusion is consistent with available chloride data, which only exist for non-seawater intruded areas. No additional data exist between MCWD production well MCWD-30 and the cluster of wells located northwest of MCWD's production wells, where TDS concentrations exceed 10,000 mg/L. Therefore, the actual location of the seawater intrusion front where groundwater TDS concentrations exceed 1,000 mg/L and/or chloride concentrations exceed 500 mg/L is unknown. The location of the seawater intrusion front in the vicinity of these wells has been identified as a data gap.

The estimated extent of sweater intrusion shown on Figure 5-28 is generally consistent with MCWRA's mapped extent of the current (2019) seawater intrusion front in the 400-Foot Aquifer (see Appendix 5-B). MCWRA also maps a similar seawater intrusion front in the 180-Foot Aquifer in the Monterey Subbasin. However, as discussed Chapter 4 and shown above, the 180-Foot Aquifer in the Subbasin is divided by an intermediate aquitard into an upper zone and a lower zone. There is no observed seawater intrusion in the upper portion of the 180-Foot Aquifer. Therefore, MCWRA's maps are only consistent with data collected from the lower 180-Foot Aquifer.

Figure 5-28 also presents the mapped Fall 2017 groundwater elevations for the lower 180-Foot Aquifer and the 400-Foot Aquifer. The figure shows that depressed groundwater elevations in the 180/400 Foot Aquifer Subbasin are creating inland groundwater gradients that are contributing to seawater intrusion within the Monterey Subbasin. This observed inland gradient is generally parallel to the current seawater intrusion front.

Since groundwater elevations in the Deep Aquifers are lower than sea level and also lower than groundwater elevations within the 400-Foot Aquifer, there is a significant risk that seawater intrusion will occur in this aquifer. Such seawater intrusion could either occur from lateral migration of seawater within the Deep Aquifers from subsea outcrops located further off-shore or and/or downward vertical migration from the intruded 400-Foot Aquifer. However, the locations and mechanisms of the Deep Aquifers recharge are not well understood. Therefore, the likelihood of and potential timeframe for seawater intrusion in this aquifer is unknown.

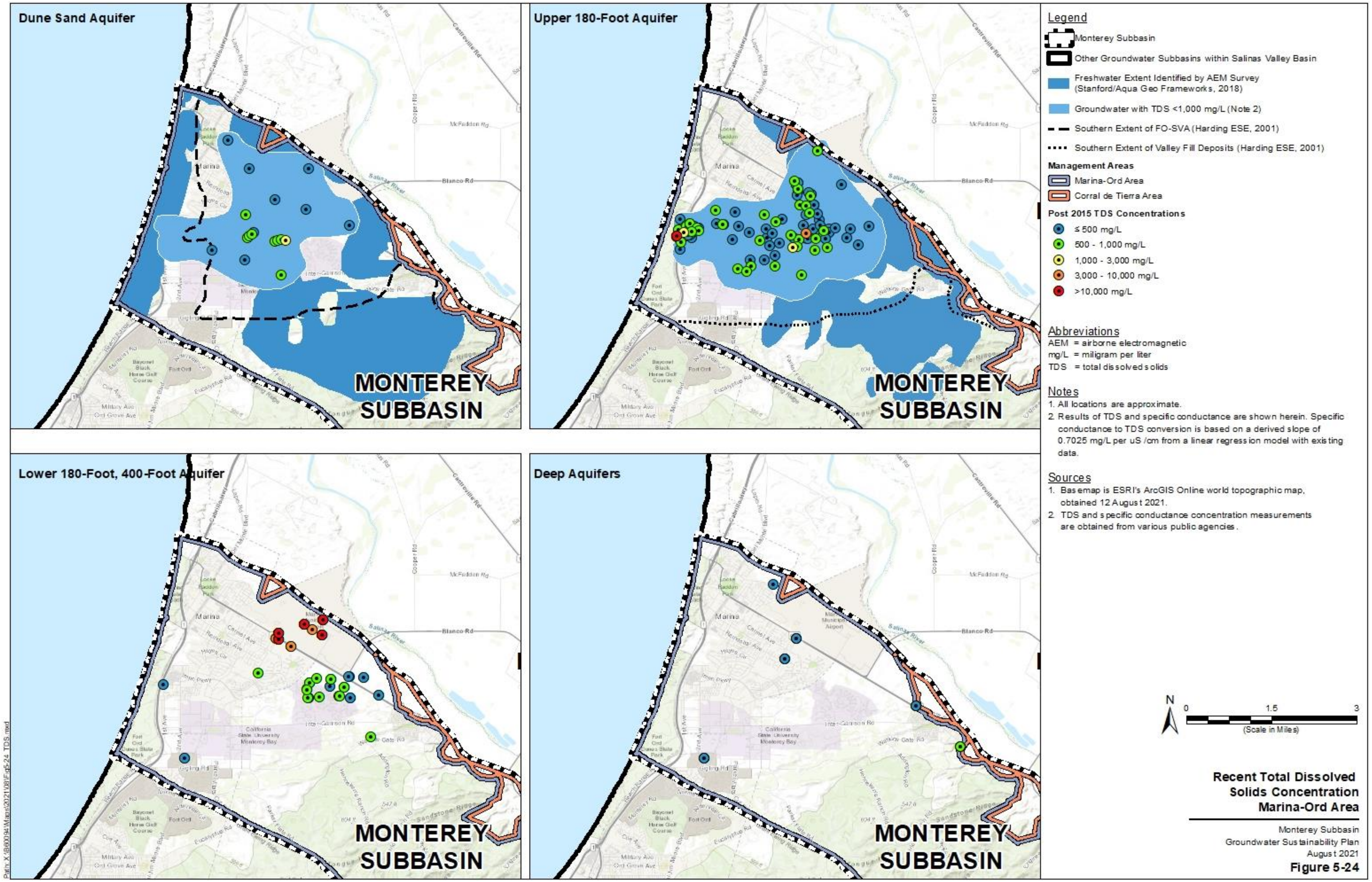



**Figure 5-24. Recent Total Dissolved Solids Concentration, Marina-Ord Area**

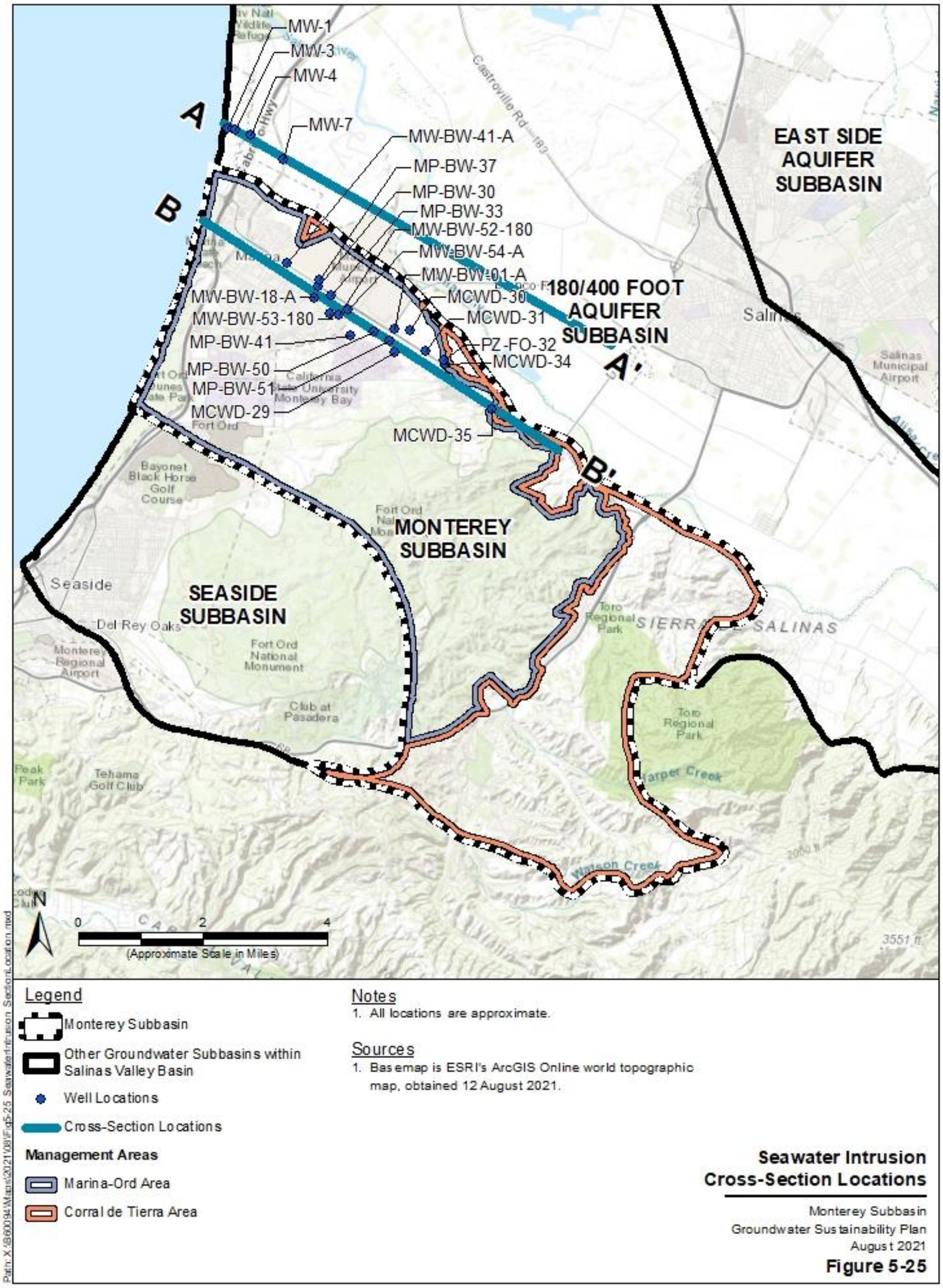



**Figure 5-25. Seawater Intrusion Cross-Section Locations**

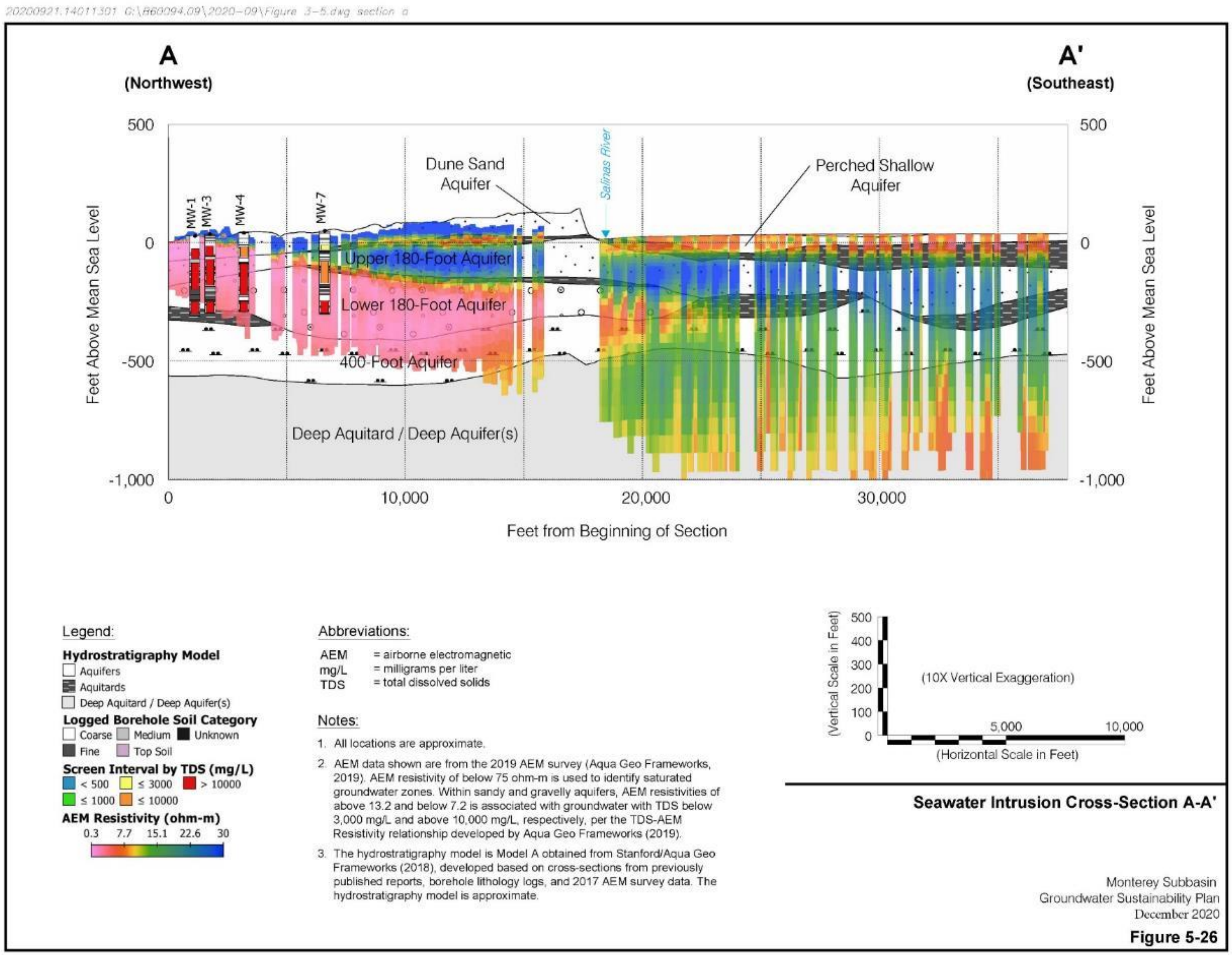



**Figure 5-26. Seawater Intrusion Cross-Section A-A'**

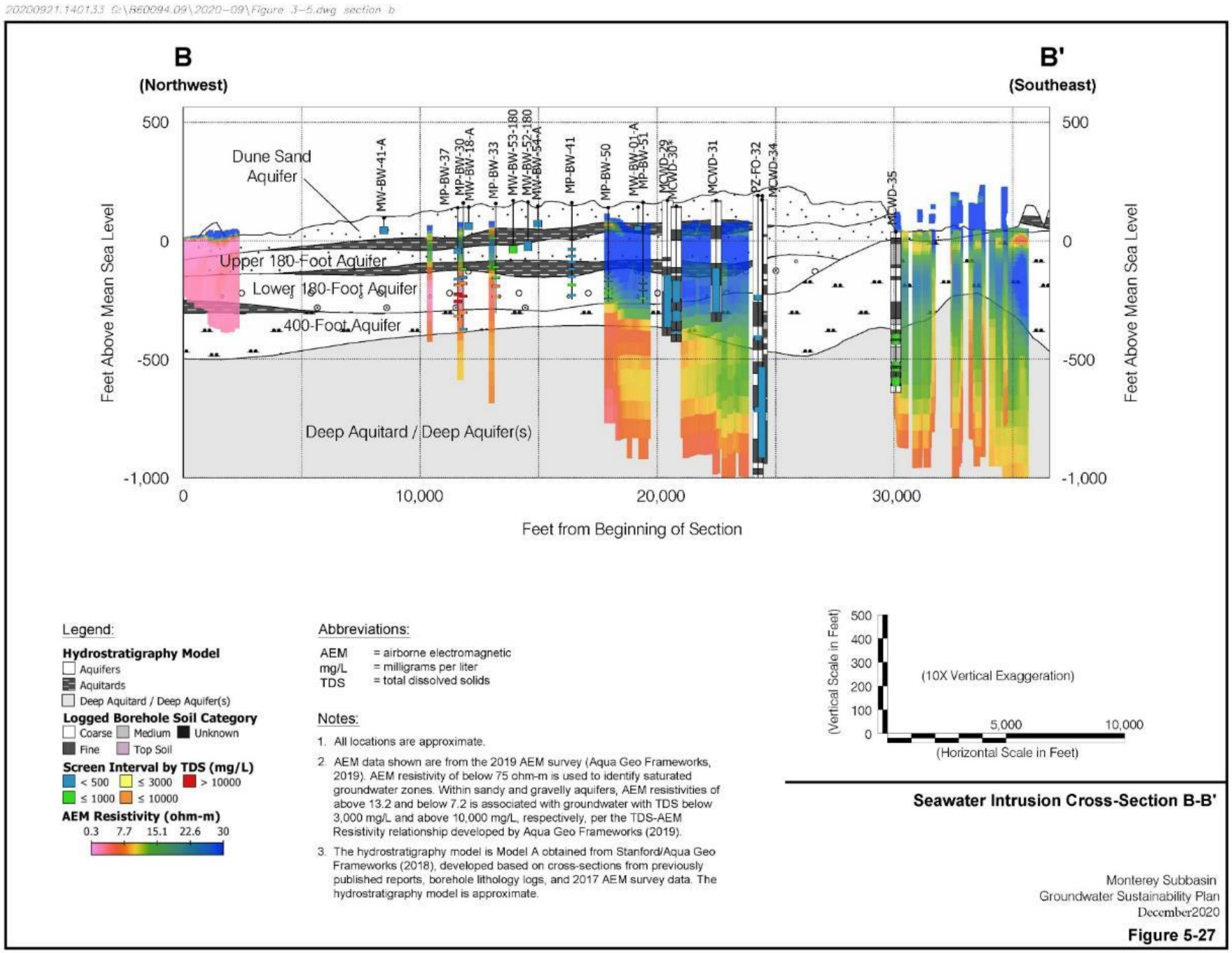



**Figure 5-27. Seawater Intrusion Cross-Section B-B'**

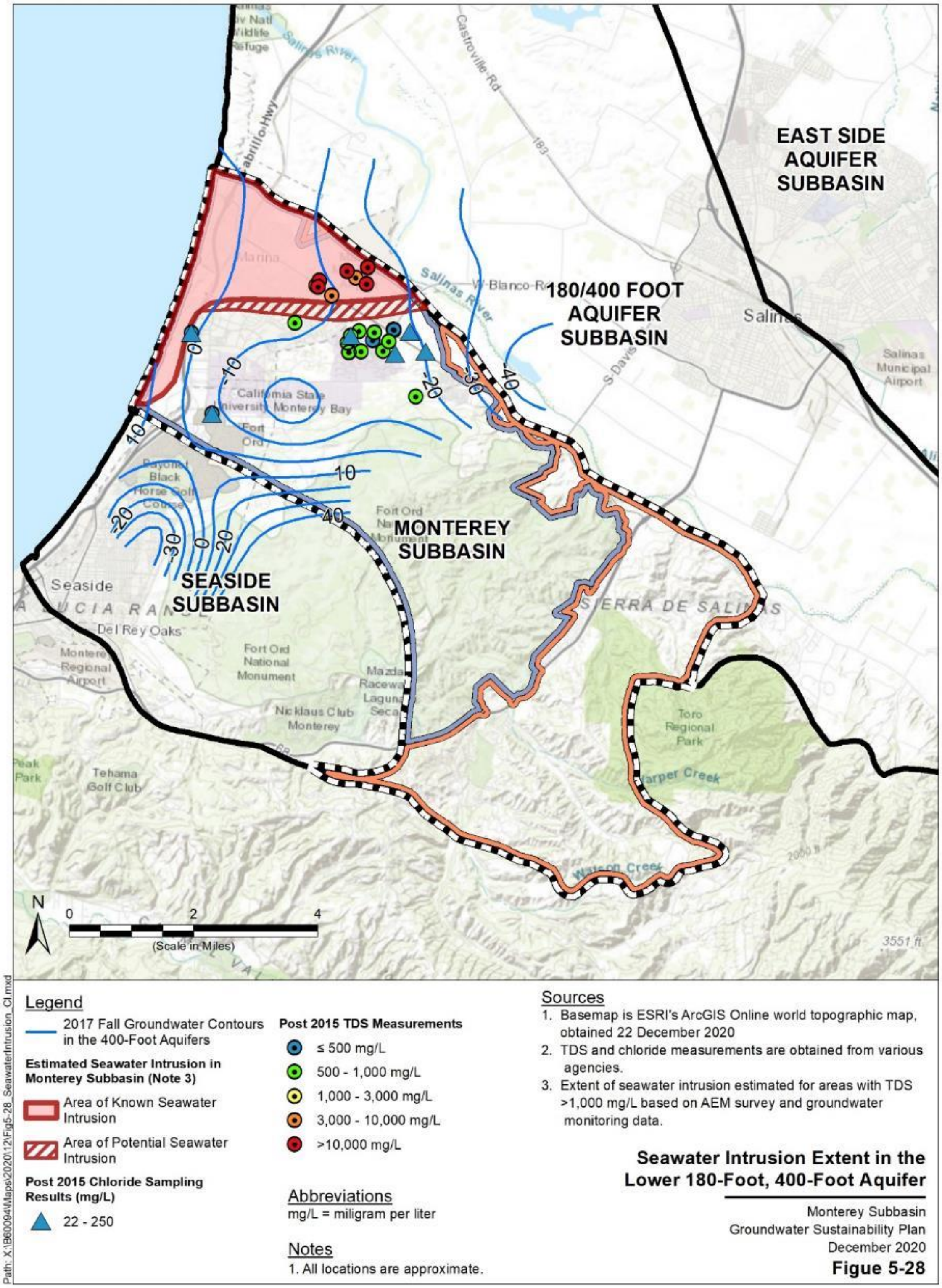



**Figure 5-28. Seawater Intrusion Extent in the Lower 180-Foot, 400-Foot Aquifer**

### 5.3.4 Historical Progression of Seawater Intrusion

Seawater intrusion has been documented in the Salinas Valley Basin since the 1940s (DWR, 1946). However, records of the water quality indicators related to seawater intrusion within the Subbasin are only available back to the 2000s and at selected locations. Thus, the spatial variability of water quality data are insufficient to access the historical rate of seawater intrusion within the Subbasin. In this section, TDS trends in selected wells near the seawater intrusion front are presented to evaluate historical seawater intrusion rates.

Seven wells screened within the lower 180-Foot and 400-Foot Aquifers with relatively long TDS records are shown on Figure 5-29. Increasing Long-term trends in TDS concentrations are observed in in areas that are seawater intruded. Additionally, high TDS groundwater has migrated downward within the Seawater intruded area. TDS concentrations have increased in wells screens MP-BW-35-467 (i.e., screened 467 ft bgs at MP-BW-35) and MP-BW-37-460 (screened 460 ft bgs at MP-BW-37) between 2008 and 2018. Also, TDS concentrations detected in wells MCWD-30 and MCWD-09 fluctuate significantly, which indicates that saline groundwater exists in close proximately to these wells.

The lateral extent of seawater intrusion within the Subbasin has been relatively stable over the past two decades. Specifically, immediately northwest of the seawater intrusion front, screens located from approximately 300 ft bgs to 400 ft bgs in multi-port wells MP-BW-37 and MP-BW-35 have been seawater intruded for nearly 20 years, or as long as records exist for this well. Immediately southeast of the seawater intrusion front, wells MCWD-30 and MCWD-29 have shown relatively stable TDS concentrations at or below 500 mg/L over the past decades, while two CASGEM wells in the southwestern portion of the Marina-Ord Area, MPWMD#FO-10 and MPWMD#FO-11, showed increasing TDS concentration in recent years. Seaside Basin Watermaster conducted induction logging on MPWD#FO-10 in early 2021 to study its geophysical characteristics (Feeney, 2021). Although the study did not confirm the exact cause of the elevated TDS/chloride concentration, it indicated that the well are not cross-connected through casing leakage.

The current seawater intrusion front is parallel to the groundwater flow direction in the lower 180-Foot and 400-Foot Aquifers; therefore, seawater continues to flow across the area that is intruded towards the 180/400 Foot Aquifer Subbasin, while there is minimal migration of seawater intrusion to inland areas of the Monterey Subbasin.

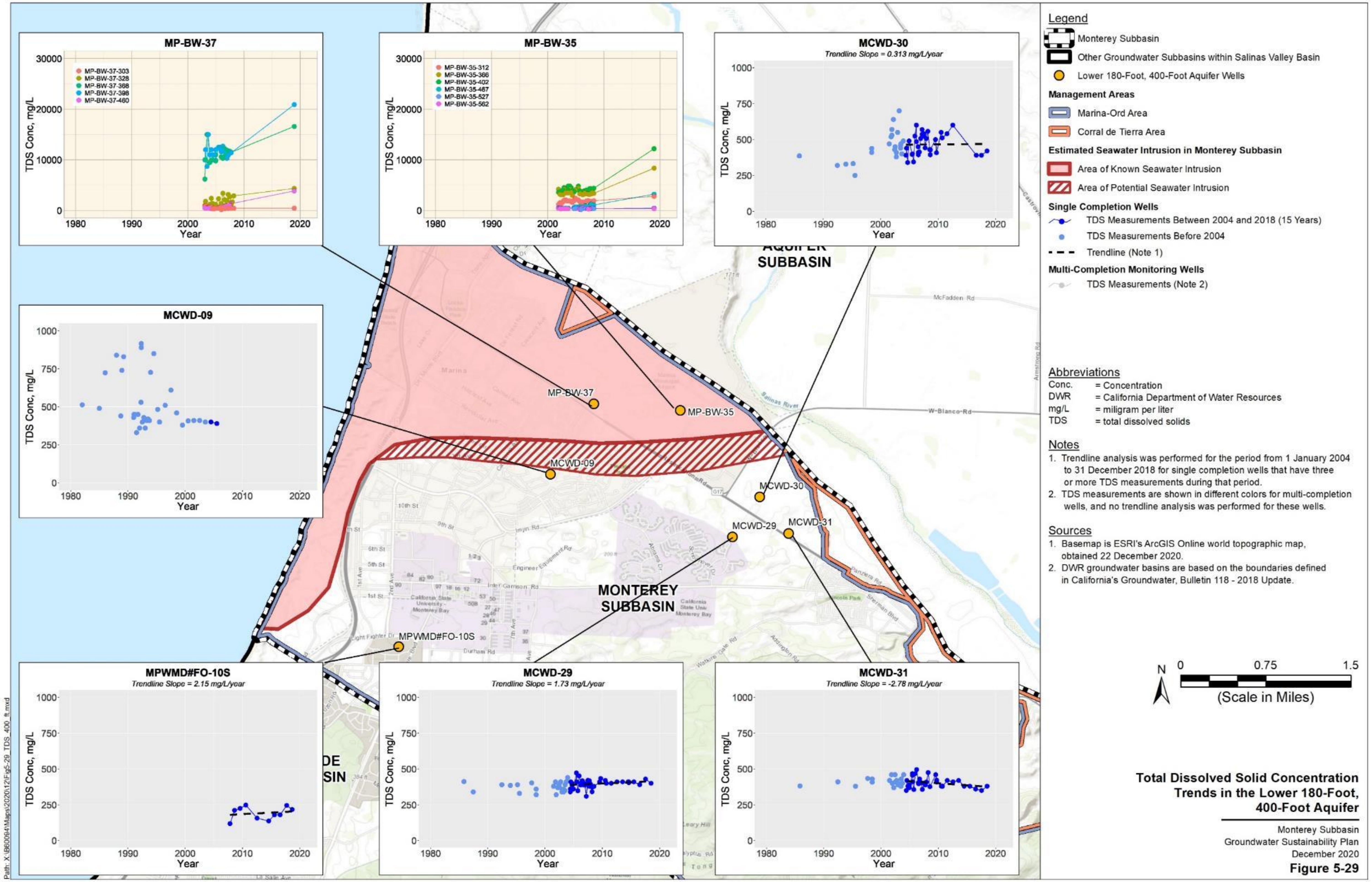



**Figure 5-29. Total Dissolved Solid Concentration Trends in the Lower 180-Foot, 400-Foot Aquifer**

## 5.4 Groundwater Quality Concerns

This section presents a summary of current groundwater quality conditions. The GSAs do not have regulatory authority over groundwater quality which is under the purview of other state and federal agencies (e.g., the Regional Water Quality Control Board). Projects and management actions implemented by MCWD and SVBGSA must not further degrade groundwater quality.

The known groundwater quality concerns in the Marina-Ord Area aquifers are elevated chloride and TDS concentrations and point-source contaminants such as Volatile Organic Carbons (VOCs) and per- and poly-fluoroalkyl substances (PFAS). The primary source of high TDS and chloride concentrations in groundwater within the Marina-Ord Area is seawater intrusion as described above in Section 5.3.

In the Corral de Tierra area, the most prevalent water quality concern is arsenic.

### 5.4.1 Data Sources

The assessment of groundwater quality conditions is based on comparing data compiled from various monitoring agencies to applicable screening levels for the various beneficial uses (i.e., Maximum Contaminant Levels [MCLs] for domestic/municipal and industrial (M&I) use and various thresholds for irrigated agricultural use).

Groundwater quality samples are collected within the Monterey Subbasin on a regular basis for various studies and programs. Groundwater quality samples have also been collected on a regular basis for compliance with regulatory programs, including drinking water and contamination cleanup programs. Groundwater quality data for this assessment were collected from:

- The US Army Corps of Engineers Fort Ord Data Integration System (FODIS);
- MPWMD;
- Seaside Watermaster;
- The USGS Groundwater Ambient Monitoring and Assessment Program (GAMA) reports (Kulongoski and Belitz, 2005; Burton and Wright, 2018);
- State Water Resources Control Board's GAMA website (SWRCB, 2020a);
- State Water Resource Control Board's GeoTracker website (SWRCB, 2020b);
- State Water Resources Control Board's Safe Drinking Water Information System (SWRCB, 2020c); and
- The California Department of Toxic Substance Control's Envirostor website (DTSC, 2020).

### 5.4.2 Distribution and Concentrations of Point-Source Contamination

Clean-up and monitoring of point source pollutants are generally under the responsibility of either State or Federal regulatory agencies such as the Central Coast Regional Water Quality Control Board

(CCRWQCB), California State Department of Toxic Substances Control (DTSC), the United States Environmental Protection Agency (U.S. EPA), and/or the United States Armed Forces. There are a number of active point-source contamination sites within the Subbasin, as identified on the SWRCB GeoTracker website[4] and the DTSC EnviroStor website[5]. These sites, shown on Figure 5-30 and listed in Table 5-2, are primarily located within the former Fort Ord and are a part of the Fort Ord's environmental cleanup program.

The former Fort Ord was placed on EPA's National Priorities List (NPL) in 1990 following environmental investigations conducted in 1984 and 1986. The same year, a Federal Facility Agreement (FFA) was signed by the Army, U.S. EPA, DTSC, and the CCRWQCB. The FFA established schedules for performing remedial investigations and feasibility studies, and required remedial actions be completed as expeditiously as possible. The base wide Remedial Investigation Feasibility Study (RI/FS) commenced in 1991. The Army performs these activities pursuant to the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) also known as Superfund.

Groundwater remedial action objectives and aquifer cleanup goals at Fort Ord are established within the Records of Decision (ROD) and subsequent Explanations of Significant Difference (ESD) prepared for each operable unit where groundwater impacts have been detected. These documents are part of the administrative record and have been endorsed by state and federal agencies. The ROD documents selected remedy and cleanup levels that complies with the federal and state requirements that are applicable or relevant and appropriate (ARAS) to the site, such as drinking water Maximum Contaminant Levels (MCLs) and CCRWQCB Basin Plan Water Quality Objectives.

The approximate extent of contamination plumes that have historically been identified in groundwater within former Fort Ord are delineated by the location of the well prohibition area, also shown on Figure 5-30 and described in detail in Chapter 3. These contamination plumes are primarily located within the Dune Sand and 180-Foot Aquifers. No contamination has been detected in the 400-Foot Aquifer and the Deep Aquifers. The most frequently detected chemicals in these areas are trichloroethene (TCE) and carbon tetrachloride (CT). In addition, there is one cleanup program site located within the City of Marina and a Leaking Underground Storage Tank (LUST) cleanup site located by Highway 68.

[4] http://geotracker.waterboards.ca.gov
[5] https://www.envirostor.dtsc.ca.gov/public/

**Table 5-2. List of Active Point Source Contamination Sites**

| Label | Site Name | Site Type | Status | Constituents of Concern |
|---|---|---|---|---|
| 1 | Don's One Hour Dry Cleaners | Cleanup Program Site | Open - Verification Monitoring | Other Chlorinated Hydrocarbons, Tetrachloroethylene (PCE) |
| 2 | Fort Ord - Fort Ord - Sites 2 and 12 | Military Cleanup Site | Open - Remediation | Chlorinated Hydrocarbons |
| 3 | Fort Ord - Fort Ord OU1 (Fritzsche Army Airfield Fire Drill Area, On-Site Plume) | Military Cleanup Site | Open - Remediation | Gasoline, Chlorinated Hydrocarbons |
| 4 | Fort Ord - Fort Ord OU1 (Off-Site Plume) | Military Cleanup Site | Open - Remediation | Gasoline, Chlorinated Hydrocarbons |
| 5 | Fort Ord - Fort Ord - OU2 | Military Cleanup Site | Open - Remediation | Gasoline, Chlorinated Hydrocarbons |
| 6 | Fort Ord - Fort Ord - OUCTP | Military Cleanup Site | Open - Remediation | Chlorinated Hydrocarbons |
| 7 | Former Exxon - Corral De Tierra | LUST Cleanup Site | Open - Eligible for Closure | Gasoline, MTBE / TBA / Other Fuel Oxygenates |
| 8 | Fort Ord Reuse Authority (Early Transfer) | Federal Superfund | Active | -- |
| 9 | Fort Ord - East Garrison (VCA) | Federal Superfund | Certified | -- |
| 10 | Fort Ord State Park-MOU with DPR | Federal Superfund | Active | -- |
| 11 | Fort Ord Reuse Authority MOA | Federal Superfund | Active | -- |

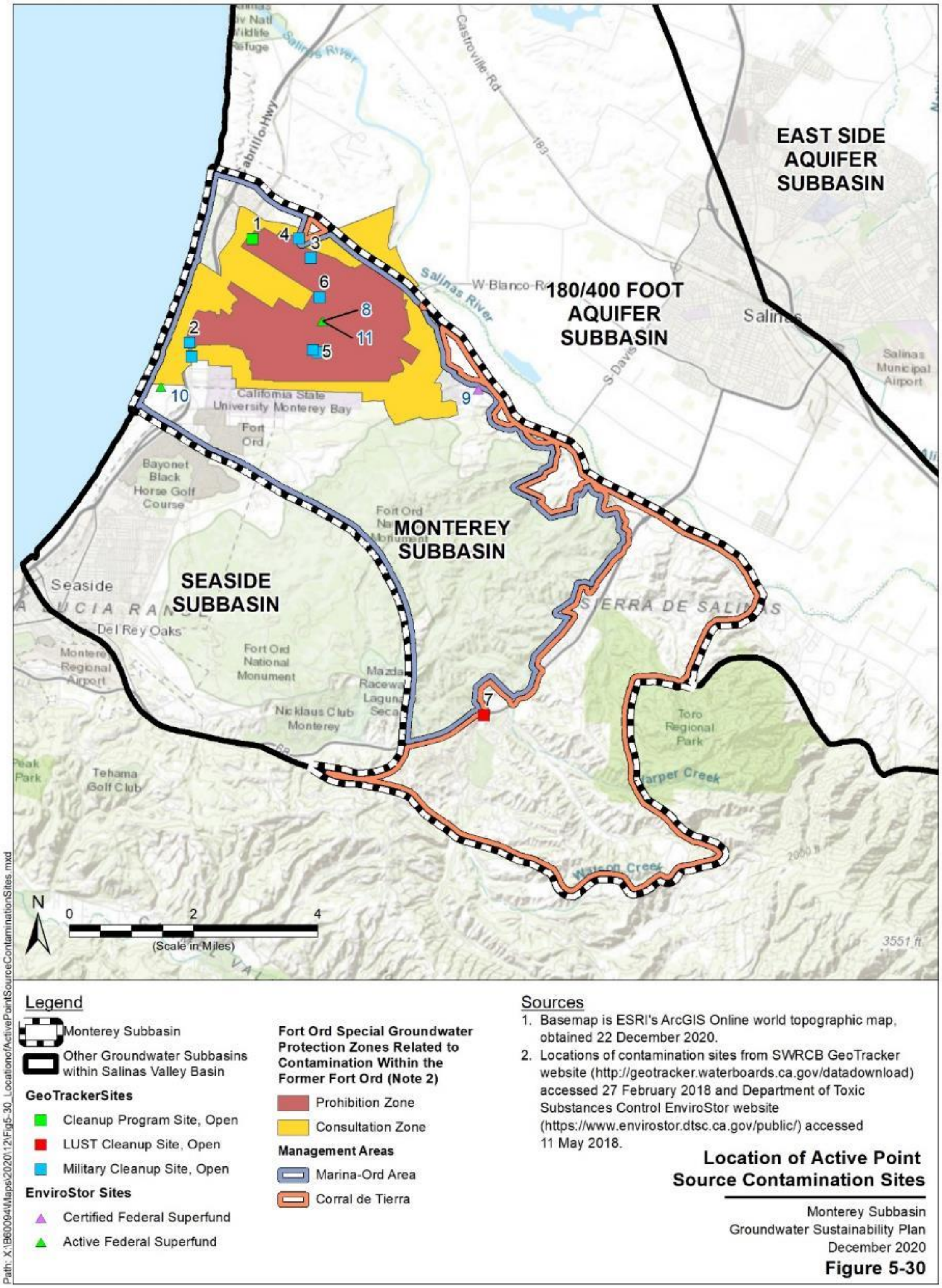



**Figure 5-30. Location of Active Point Source Contamination Sites**

To date, no point-source contaminants have been detected above MCLs in domestic/M&I supply wells within the Subbasin. However, as of June 2019, trichloroethylene (TCE), carbon tetrachloride (CT), perfluorobutanesulfonic acid (PFBS), and perfluorohexanoic acid (PFHxA) have been detected above their respectively detection limits in MCWD supply wells screened in the 180- and 400-Foot Aquifers-.

- Trichloroethylene (TCE) and carbon tetrachloride (CT): TCE and CT are among the major chemicals of concern detected in groundwater within Fort Ord Operable Unit 2 (OU2) and Operable Unit Carbon Tetrachloride Plume (OUCTP). These operable units are located in the center of the Marina-Ord Area southeast of MCWD production wells. TCE was detected in MCWD lower 180-Foot, 400-Foot Aquifer production wells since 2000s and was most recently detected at concentrations ranging from 0.57 ug/L in MCWD-30 to 1.80 ug/L in MCWD-29 in June 2019[6]. CT was also recently detected in these wells at low concentrations. Figure 5-31 illustrates TCE concentrations detected in Fort Ord monitoring wells and MCWD production wells in June 2019. As shown on Figure 5-31, within the former Fort Ord, TCE exceeding the MCL (5 ug/L) was detected in monitoring wells in the Dune Sand Aquifer as well as the upper and lower 180-Foot Aquifers. Discontinuity of aquitards and the downward vertical groundwater gradient have contributed to downward migration of contamination. The closest monitoring well with TCE concentration detected above the MCL is located in the lower 180-Foot Aquifer one mile upgradient of MCWD production wells.
- Perfluorobutanesulfonic acid (PFBS) and perfluorohexanoic acid (PFHxA): PFBS and PFHxA are Per-poly-fluoroalkyl substances (PFASs), which is a group of emerging man-made contaminants that were used in firefighting foam, protective coatings, and stain and water-resistant products until the 2000s. During MCWD's January 2020 PFAS sampling event, PFBS and PFHxA were detected in lower 180-Foot, 400-Foot Aquifer production well MCWD-29. There are no current drinking water regulations in California for these two substances. To date, no sampling of PFBS and PFHxA has been conducted in non-MCWD wells.

  In 2019, the USACE conducted a review of historical activities with the potential to cause PFAS contamination at the Fort Ord (USACE, 2019). The study identified that the primary mechanism for release of PFAS was through the historical use of Aqueous Film-Forming Foam (AFF) in former fire drill areas, aviation areas, and subsequent transport to landfill and sewage treatment areas. Additionally, groundwater sampling for the two PFAS contaminants with established regulatory limits (Perfluorooctanoic acid [PFOA] and perfluorooctanesulfonic acid [PFOS]) was conducted as part of the study. The United States Environmental Protection Agency (U.S. EPA) issued a lifetime health advisory for PFOA and PFOS in drinking water at a total concentration of 0.07 ug/L. Even though no MCLs have been promulgated, the California SWRCB established notification levels (NLs) for PFOA and PFOS at 0.0051 ug/L and 0.0065 ug/L, respectively. PFOA and PFOS were measured above their respective NLs in the Dune Sand 180-Foot Aquifers that are adjacent to the Fort Ord OU2 Landfill.

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[6] The MCL for TCE is 5 ug/L.

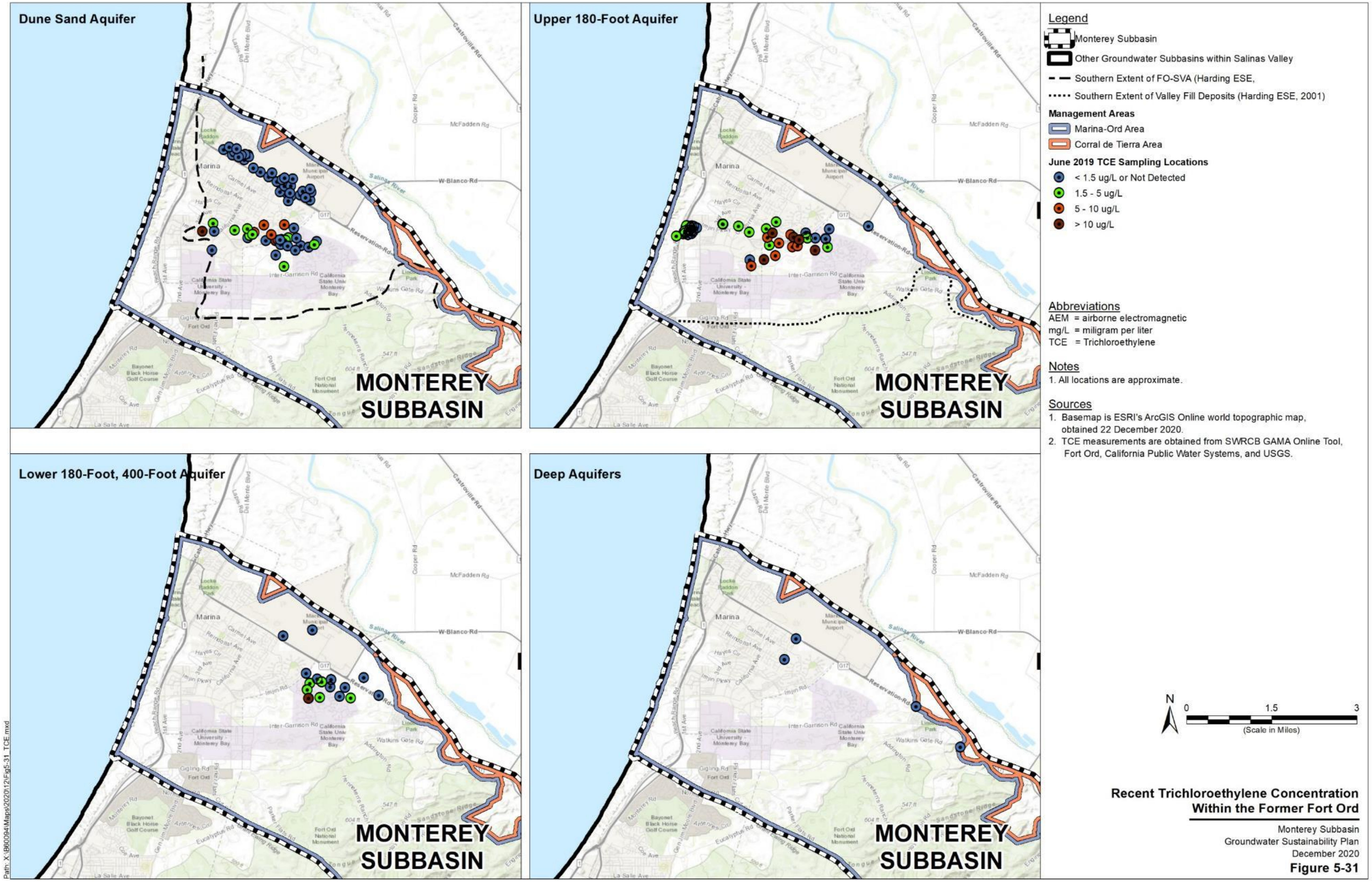



**Figure 5-31. Recent TCE Concentration within the Former Fort Ord**

### 5.4.3 Distribution and Concentrations of Diffuse or Natrual Groundwater Constituents

In addition to the single point source of groundwater contamination described above, the CCRWQCB monitors and regulates activities and discharges that can contribute to non-point source pollutants, which are constituents released to groundwater over large areas.

In the El Toro Primary Aquifer System, the most prevalent non-point source water quality concern is arsenic. It has been reported that primary and secondary MCLs are exceeded in several wells in the area with arsenic being a constituent of concern for additional groundwater development (GeoSyntec, 2007). In addition, nitrate and coliform bacteria may present problems in areas with more dense occurrences of septic tanks and shallow wells (GeoSyntec, 2007). Concentrations of TDS range from 355 to 1650 mg/L (DWR 1967; GeoSyntec, 2007). However, there is some variability between hydrostratigraphic units.

Groundwater quality conditions in the basin were summarized in two USGS water quality studies. The USGS 2005 GAMA study in the Salinas Valley characterized deeper groundwater resources used for public water supply (Kulongoski and Belitz, 2005). The USGS 2018 GAMA study in the Salinas Valley focused on domestic well water quality (Burton and Wright, 2018). All quality-assured data collected for these two studies and the GAMA Program are publicly available through the SWRCB GAMA and GeoTracker groundwater information systems (SWRCB, 2020a; SWRCB, 2020b).

Table 5-3 reports the constituents of concern in the Monterey Subbasin based on GAMA and GeoTracker data. These data include domestic wells monitored under the Domestic Irrigation Lands Regulatory Program (ILRP), agricultural supply wells sampled under the Irrigation ILRP, as well as public supply wells monitored under the Department of Drinking Water (DDW) programs. As such, Table 5-3 compares sampling results to applicable screening levels for the various beneficial uses (i.e., MCLs for domestic/M&I use and various thresholds for irrigated agricultural use). The number of wells that exceed the regulatory standard for any given constituent of concern is based on the latest sample for each well in the monitoring network. Not all wells have been sampled for all constituents of concern. Therefore, the percentage of wells with exceedances is the number of wells that exceed the regulatory standard divided by the total number of wells that have ever been sampled for that constituent of concern. Figure 5-32 shows the location of GAMA/GeoTracker database wells with identified exceedances a regulatory standard in its latest sample.

As shown on Table 5-3, arsenic is the only constituent with a primary MCL standard and a significant percentage of wells with exceedances found within the Subbasin. It should be noted that ILRP often does not sample for arsenic, thus, the impact arsenic has had on ILRP domestic and irrigation wells is unknown. This will be a data gap addressed during GSP implementation, especially in shallow domestic wells.

Iron and manganese have been detected above their respective secondary MCLs in over 10% of DDW wells. The only two Irrigation ILRP wells within the Subbasin, located along the northern Subbasin boundary, have shown exceedances of total Nitrate and Nitrite. However, no nitrate exceedances have been identified in any domestic or public drinking water supply wells.

**Table 5-3. GAMA/GeoTracker Water Quality Summary**[7]

| Constituent of Concern | Regulatory Exceedance Standard | Standard Units | Historical Number of Monitoring Wells Sampled | Number of Wells Exceeding Regulatory Standard from latest sample | Percentage of Wells with Exceedances |
|---|---|---|---|---|---|
| Domestic ILRP Wells (Data from March 2013 to December 2017) | | | | | |
| **Total Dissolved Solids** | 1000 | MG/L | 7 | 1 | 14% |
| DDW Wells (Data from April 1990 to May 2020) | | | | | |
| **Arsenic** | 10 | UG/L | 33 | 7 | 21% |
| **Chloride** | 500 | MG/L | 33 | 1 | 3% |
| **Iron** | 300 | UG/L | 32 | 13 | 41% |
| **Manganese** | 50 | UG/L | 31 | 11 | 35% |
| **Nickel** | 100 | UG/L | 33 | 1 | 3% |
| **Specific Conductance** | 1600 | UMHOS/CM | 33 | 2 | 6% |
| **Total Dissolved Solids** | 1000 | MG/L | 32 | 2 | 6% |
| **Zinc** | 5 | MG/L | 32 | 1 | 3% |

[7] Inactive, abandoned, or destroyed wells are excluded from this analysis.

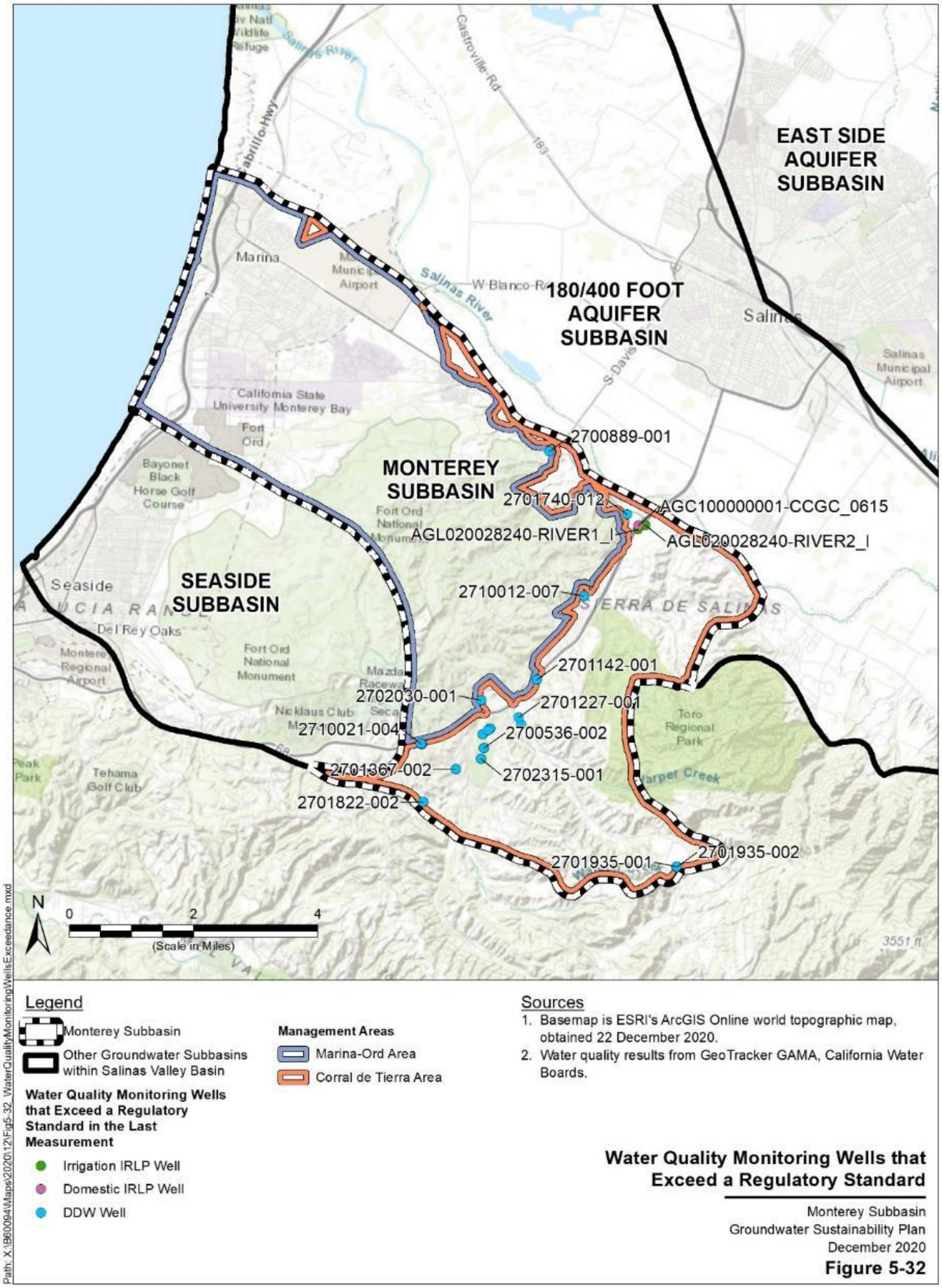



**Figure 5-32. Water Quality Monitoring Wells that Exceed a Regulatory Standard**

## 5.5 Land Subsidence

Land subsidence, or the lowering of ground surface, can be caused by excessive groundwater withdrawal that lowers the potentiometric head in compressible fine-grained layers, resulting in depressurization and compaction of those fine grain layers. Land subsidence can be elastic or inelastic. Elastic subsidence is reversible (i.e., the land surface rises again after the potentiometric head increases) whereas inelastic subsidence is irreversible (i.e., the compaction of fine-grained layers is permanent). Inelastic subsidence is considered an undesirable result.

### 5.5.1 Data Sources

This assessment uses Interferometric Synthetic Aperture Radar (InSAR) satellite data[8] from June 2015 to September 2019. These are the only available data used for estimating subsidence in this GSP.

### 5.5.2 Subsidence Mapping

Figure 5-33 presents a map showing average annual subsidence rate in the Monterey Subbasin over the period from June 2015 and September 2019. The yellow area on the map is the area with measured average annual changes in ground elevation of between -0.1 and 0.1 foot per year. As discussed further in Chapter 8, because of inherent error in the InSAR measurement methodology, any measured ground level changes between -0.1 and 0.1 foot per year is considered an area of no subsidence. The map shows that no measurable subsidence has been recorded anywhere in the Monterey Subbasin.

[8] https://gis.water.ca.gov/arcgisimg/rest/services/SAR/Vertical_Displacement_TRE_ALTAMIRA_v2019_Total_Since_20150613_Mosaic/ImageServer

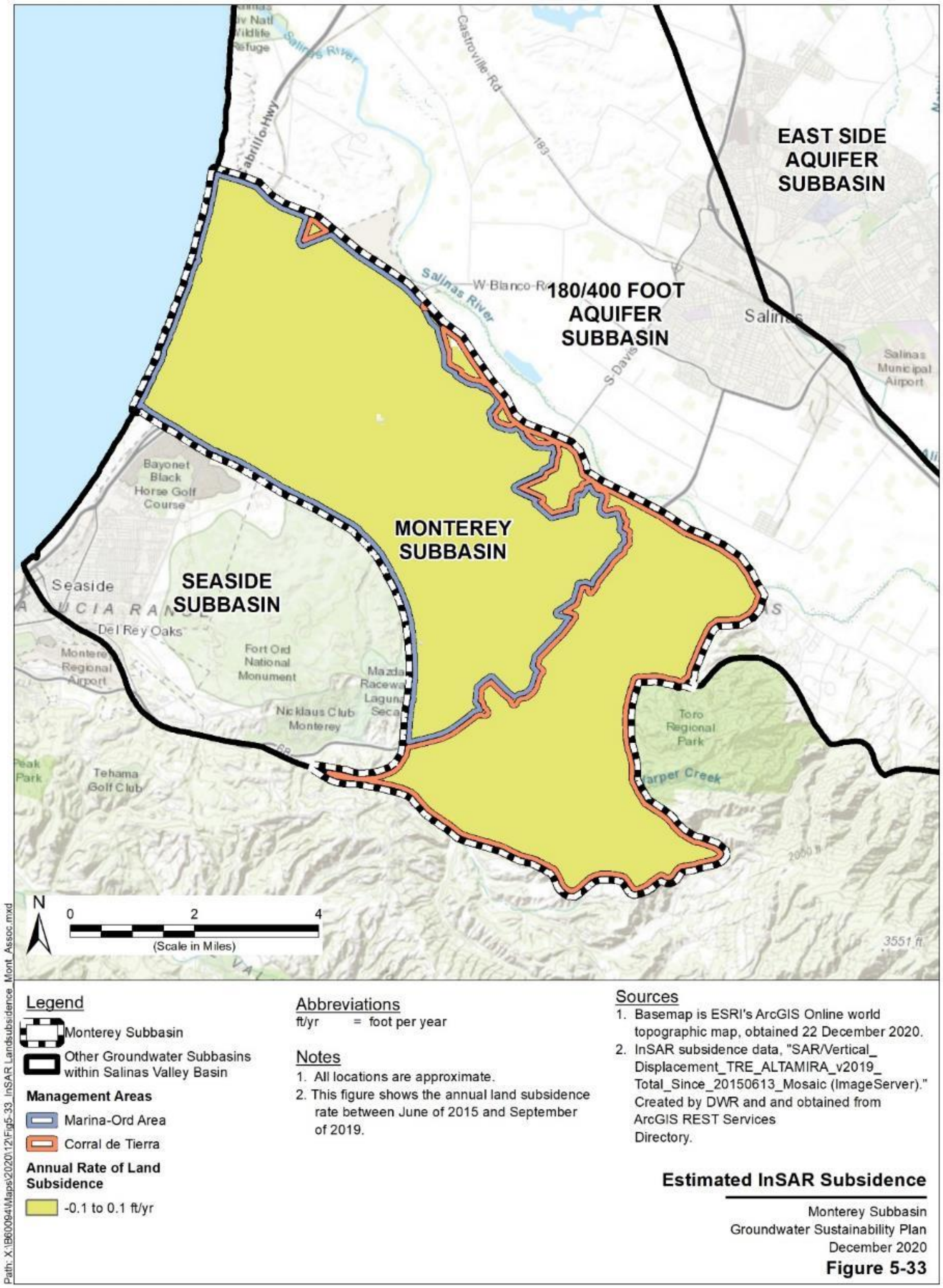
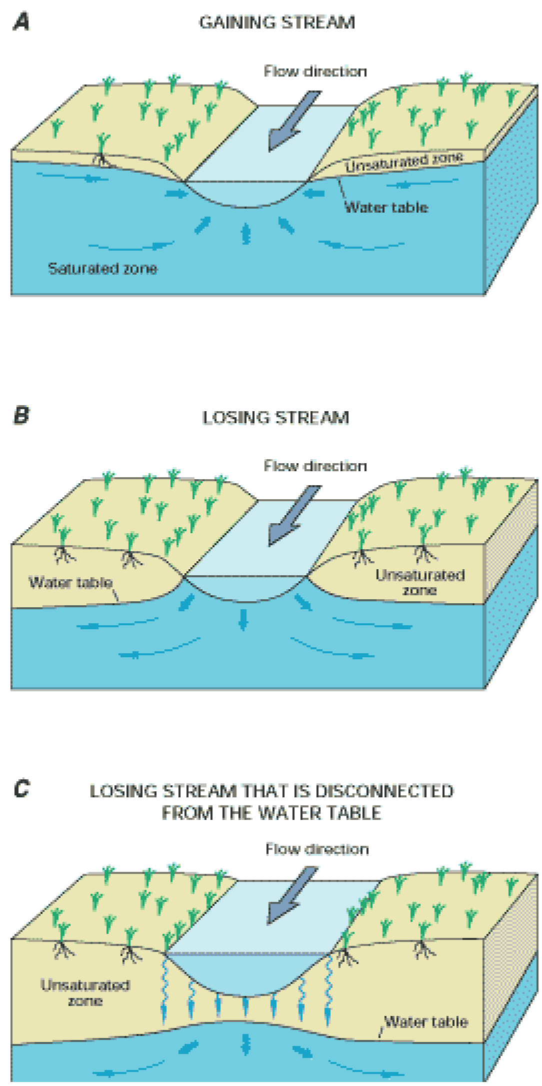



**Figure 5-33. Estimated InSAR Subsidence**

## 5.6 Interconnected Surface Water Systems

Surface water that is connected to the groundwater flow system is referred to as interconnected surface water. If the groundwater elevation in an aquifer that is hydraulically connected to a stream (or other surface water body) is higher than the water level in the stream, the stream is said to be a gaining stream because it gains water from the surrounding underlying groundwater. If the groundwater elevation is lower than the water level in the stream, it is termed a losing stream because it loses water to the surrounding groundwater flow system. If the groundwater elevation is well below the streambed elevation and there is an unsaturated zone between the stream and the groundwater, the stream and groundwater are considered to be disconnected. These concepts are illustrated in Figure 5-34.

**Figure 5-34. Conceptual Representation of Interconnected Surface Water (Winter et. al., 1999)**



### 5.6.1 Data Sources

This analysis of interconnected surface water is based on best available data but contains significant uncertainty. The main source of information for this analysis will be the Monterey Subbasin groundwater model and the SVIHM when they become available. Subject to limitations related to model resolution and overall accuracy, the models will be able to provide a detailed picture of the distribution of hydraulically connected surface water and groundwater in the Subbasin. The assessment herein uses groundwater elevation measured in the shallow-most principal aquifers (i.e., the Dune Sand Aquifer in the coastal Marina-Ord area and the Aromas Sands/Paso Robles Aquifer in the upland Corral de Tierra area) to identify potential hydraulic connection. As shown below, shallow groundwater elevation is limited within the Subbasin and additional groundwater monitoring wells may be necessary to verify groundwater elevations adjacent to surface water bodies. This is a data gap that will be addressed during GSP implementation. An evaluation of surface water depletion rates is provided in Chapter 6.

### 5.6.2 Analysis of Surface Water and Groundwater Interconnection

As described in Section 4.3, surface water streams within the Subbasin are generally small intermittent streams that flow only after storm events, and are unlikely to be connected to groundwater, except for the lower reaches of El Toro Creek and two potential locations along the Salinas River near the Monterey-180/400-Foot Aquifer Subbasin boundary where the Salinas River intercepts the Subbasin in a small portion of the Corral de Tierra Area.

El Toro Creek is a perennial stream below the confluence with Watson Creek below the Corral de Tierra golf course, and runoff-dependent above this point (Feikhart, 2001). Recorded stream flows at USGS gage 11152540 from 1961 to 2001 indicate a mean annual streamflow of 1,590 AFY (GeoSyntec, 2007). This mean annual streamflow was calculated for the entire record from 1961 to 2001. However, El Toro Creek did not record flow every year. It is unclear whether the perennial sections of streamflow in El Toro Creek is supported by groundwater from a principal aquifer. This will be further evaluated as more data becomes available. Other analysis may include locations of shallow groundwater. In the Salinas Valley Basin, groundwater that is within 20 feet of land surface may be assumed to be connected to surface water based on streambed incision. This may not be the case in tributaries such as El Toro Creek. No areas of groundwater within 20 feet of land surface were found in the Corral de Tierra area in Fall 2017 (Figure 5-35). However, in 2019, there were some areas of groundwater within 20 feet of land surface recorded in the Corral de Tierra area along El Toro Creek (Figure 5-36).However, there were no area groundwater within 20 feet of land surface recorded in the Corral de Tierra area along the Salinas River in Fall 2019.

Another type of surface water that exists within the Subbasin includes ponds and lakes located within the City of Marina and within the Fort Ord federal land area. These surface water features are known as vernal ponds (discussed further in Section 5.7.1 below); however, some of these features are known to contain open water well into the dry season (WRA, 2020). As shown on Figure 5-35 and discussed in Section 5.7 below, groundwater elevations in the Dune Sand Aquifer in the vicinity of the City of Marina are within 20 ft of ground surface and are at similar levels in nearby Dune Sand Aquifer wells. Therefore, the ponds in the vicinity of City of Marina may be supported by groundwater in the Dune Sand Aquifer. There are several shallow groundwater wells within approximately 1,500 feet of the Marina Ponds. No existing shallow groundwater exist in the vicinity of the ponds within the former Fort Ord federal lands area.

For areas of the Subbasin that are connected to surface water and groundwater extraction exits, a detailed analysis of hydraulic connection is required. These areas may require additional evaluation of hydraulic interaction, which will be possible a numerical model, once available.  Additional data are needed to reduce uncertainty and refine the map of interconnected surface waters.

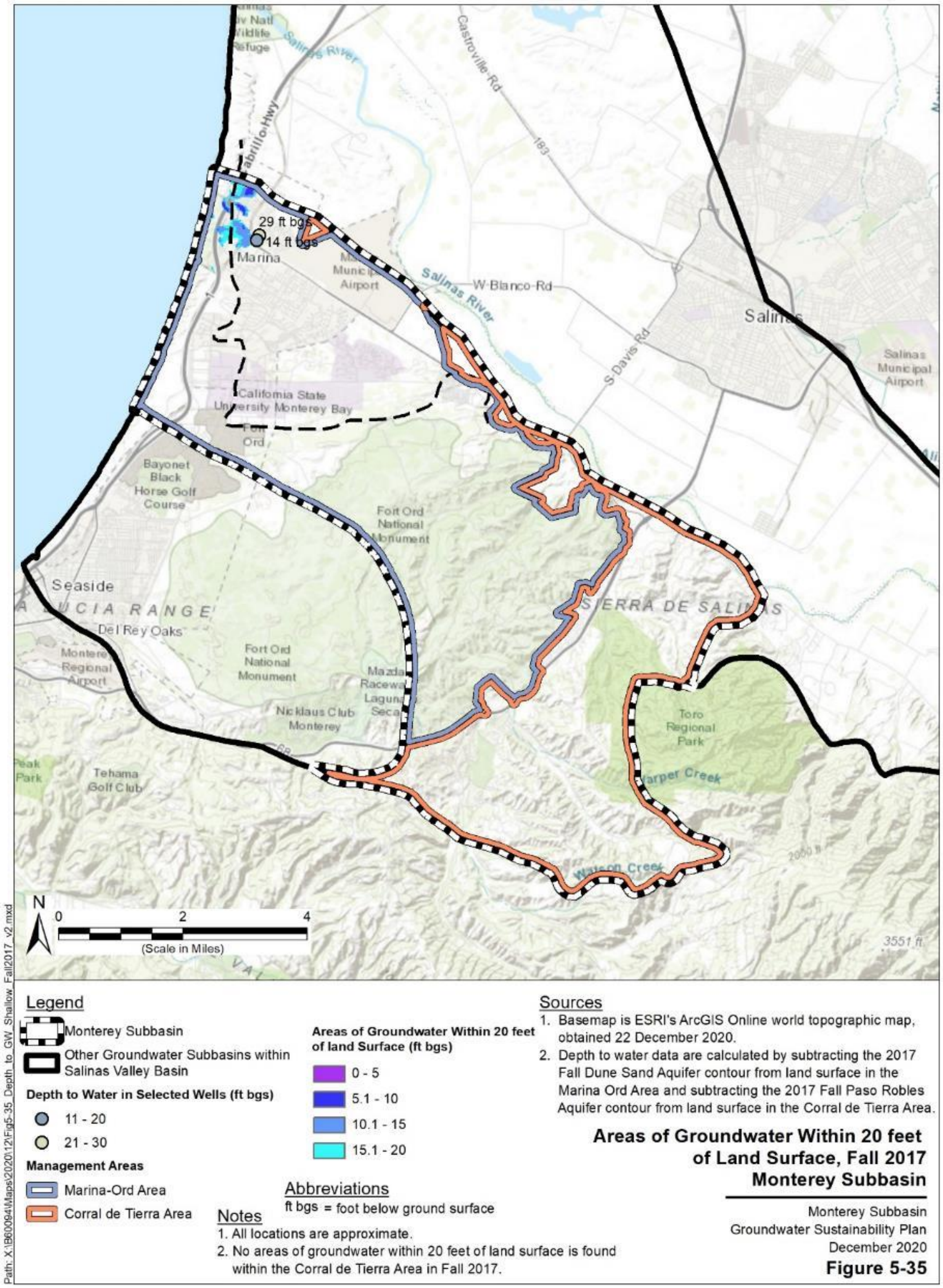



**Figure 5-35. Areas of Groundwater Within 20 feet of Land Surface, Fall 2017, Monterey Subbasin**

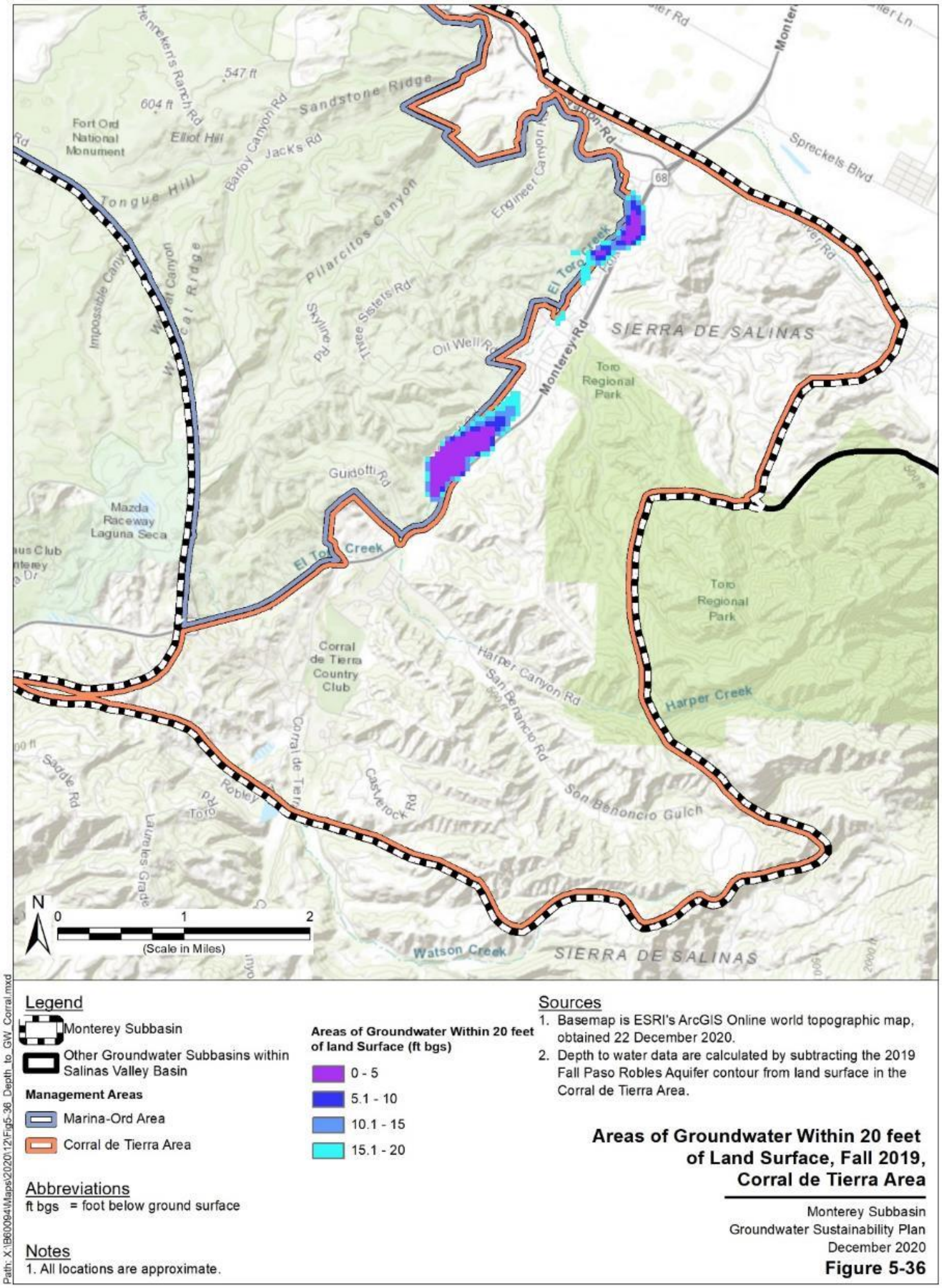



**Figure 5-36. Areas of Groundwater Within 20 feet of Land Surface, Fall 2019, Corral de Tierra Area**

## 5.7 Groundwater Dependent Ecosystems

Groundwater Dependent Ecosystems (GDEs) are natural communities (flora and fauna) that depend on near-surface groundwater as a source of water. While GDEs are not a sustainability indicator as defined by SGMA, they are considered a beneficial use of groundwater and are potentially affected by other sustainability indicators such as chronic lowering of groundwater levels, and therefore must be considered in GSPs. Figure 5-37 shows the distribution of potential GDEs within the subbasin based on DWR's mapping of "Natural Communities Commonly Associated with Groundwater" (NCCAG), modified by information from local habitat management plans and studies. Three GDE and potential GDE units were identified in the Monterey Subbasin and are described below.

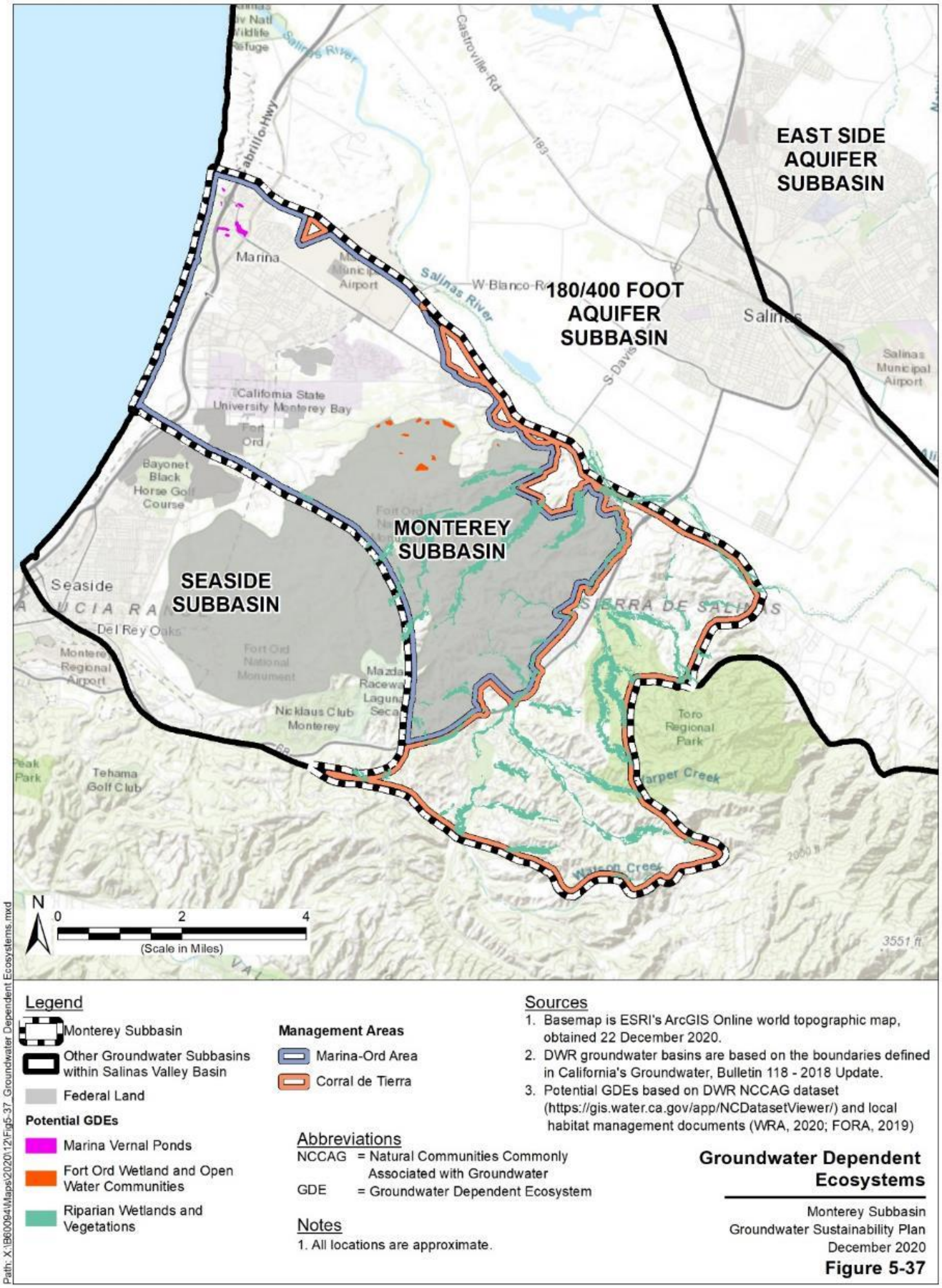



**Figure 5-37. Groundwater Dependent Ecosystems**

### 5.7.1 Coastal Vernal Ponds within the City of Marina

Vernal ponds are located in the northwestern portion the Subbasin within the City of Marina. These vernal ponds are "seasonal ponds which expand during wet season and support marshy wetlands much of the years" (City of Marina, 2013). A recent study conducted by the WRA Environmental Consultants (2020) identified the hydrologic conditions of the Marina vernal ponds and included site visits in June 2020. The study concluded that the ponds are reliant upon groundwater and should therefore be considered GDEs (WRA, 2020).

WRA observed five aquatic and three upland biological communities at the six ponds. Among those communities were Willow Riparian Forest, Coastal Freshwater Marsh, and Costal Saltwater Marsh communities totaling 19.51 acres. These communities were observed with features that are dependent upon groundwater. Specifically, species that rely on a source of year-round water supply were identified within each pond. A high-water level was observed at each pond that is similar to the groundwater elevations in the Dune Sand Aquifer. All ponds except for Pond 5 contained open water at the time of the site visit in June 2020.

The study concluded that vegetation associated with the GDEs at these ponds was in good condition.

### 5.7.2 Wetlands and Open Water Communities Within the Former Fort Ord

Several wetland and open water communities, including vernal ponds and freshwater marshes, are located in the northeastern Fort Ord area (ICF, 2019). There are no shallow groundwater data available in the vicinity of these wetland and open water communities within the former Fort Ord. Therefore, additional shallow groundwater information and field reconnaissance is necessary to verify the existence of these potential GDEs, and whether they constitute true GDEs.

These potential GDEs within the former Fort Ord are located within the federal land areas of the Subbasin not subject to SGMA. Several of these communities are located within the Fort Ord Munition Response Area where munition investigation activities that may disturb these wetlands have been carried out by FORA under the Environmental Services Cooperative Agreement (ESCA) with the Army. These communities as well as other natural resources within the former Fort Ord are being managed and monitored by the USACE, FORA, and ESCA Remediation Response (RP) Team pursuant to the Fort Ord Habitat Management Plan (HMP; USACE, 1997), the FORA Habitat Conservation Plan (HCP; FORA, 2019), and the US Fish and Wildlife Service (USFWS) Biological Opinions (BOs) applicable to Fort Ord. The HMP and BOs identify mitigation measures to minimize impacts during pre-disposal activities. The HCP supersedes the HMP as the primary species and habitat conservation planning document for non-Federal recipients of Fort Ord lands.

### 5.7.3 Riparian Wetlands and Vegetations

Areas of riparian wetlands and vegetation near local streams and creeks have been identified as NCCAG within the subbasin. The NCCAG datasets are based on aerial imagery interpretation and are not verified with field studies. These potential GDEs need to be combined with additional analyses to determine whether these wetlands and vegetation are truly groundwater dependent.

Additional shallow groundwater data and field reconnaissance are necessary to verify whether these communities truly rely on groundwater and whether shallow groundwater that these locations are connected with one of the principal aquifers, as not all riparian ecosystems are groundwater-dependent; some may be sustained by soil water content. As discussed above, riparian areas that appears to have near-surface groundwater (within 20 feet of land surface) within the principal 400-Foot/Aromas Sands/Paso Robles Aquifer are only identified along El Toro Creek. Insufficient shallow well data are available to sufficiently confirm the depth to groundwater near these potential GDEs.

Therefore, these GDE units remain as a potential GDE and should be verified by additional shallow groundwater data in the vicinity of these units, updated field methodologies, and on-the-ground tracking.